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A comparison of reading on computer screens and print media: measurement of attention patterns using EEG

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A comparison of reading on computer screens and print media: measurement of attention patterns using EEG

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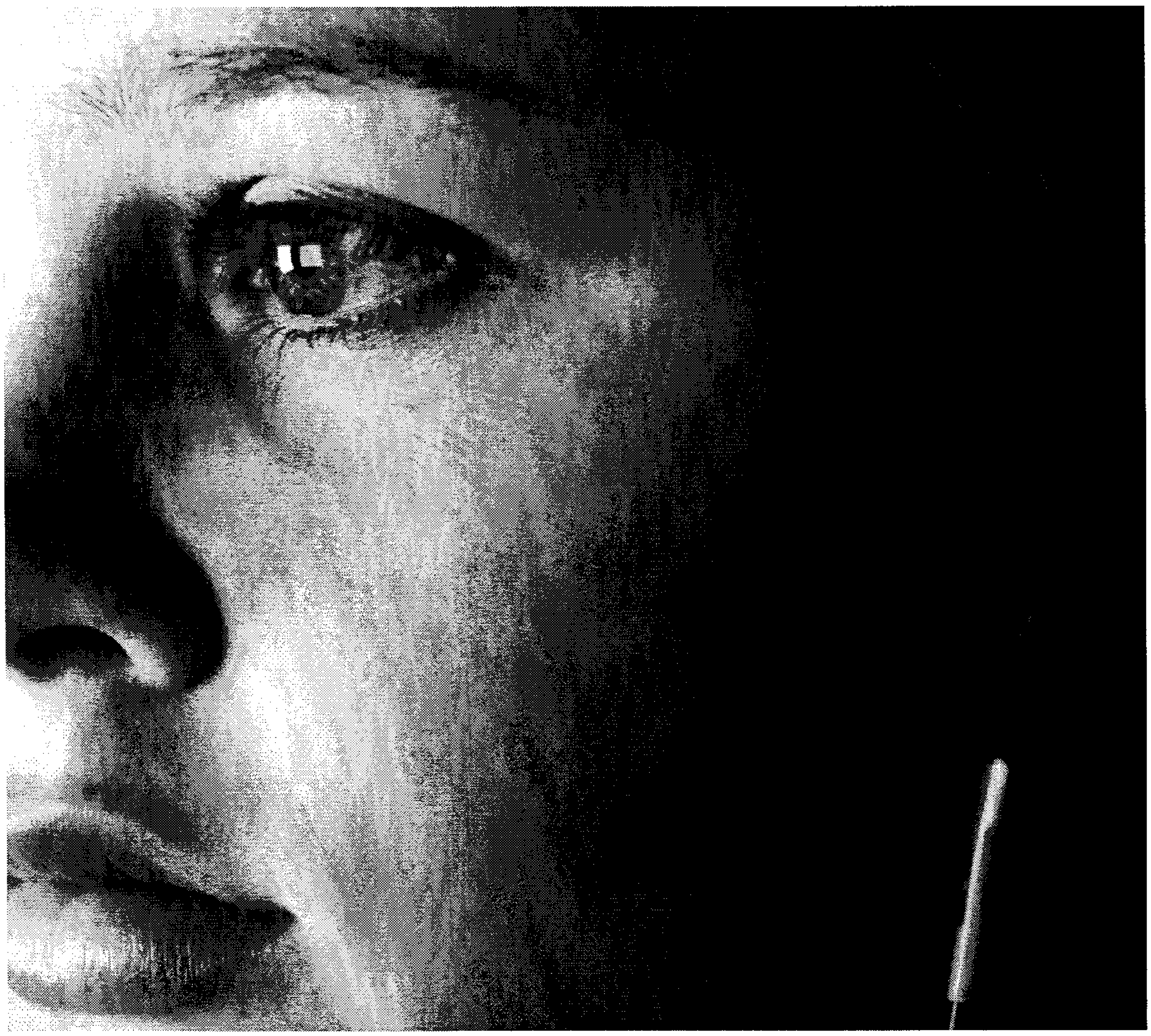
CHAPTER ONE • INTRODUCTION



The purpose of this study is to see if media choice affects attention patterns for subjects reading text. Anecdotally, this researcher, educators and others have noticed when the Internet is used, many people print out lengthy or difficult reading material presented on a computer screen "so they can read it" or so that they can "understand it." A series of typography studies done in the mid-1990's confirms that typography for the computer screen does differ from print standards for ease of reading.

This study is focused particularly on visual information and the visual processing areas of the brain and measures attention patterns related to reading.

From a biological standpoint and as outlined by Edelman, who proposes the Theory of Neuronal Group Selection (TNGS) and which is also referred to as Neural Darwinism (see Edelman 1987, 1989, 1992, 2000, 2004), it follows that most brain functioning and learning is created by doing. It is from interaction with the environment and individual sensory stimuli that the brain, encased in a dark bony skull, receives information. The process begins as the eye sends electrical signals to the occipital and parietal lobes at the back of the brain. The occipital lobes (the ventral stream or "what" area) decode the electrical impulses and compare and contrast the information with previous experiences, which Edelman defines as reentry. From this reentry, the information is classified, whether it be as simple as recognizing a letter/word or as complicated as recognizing the face of a friend in a crowd. In each case, the information must be acquired, decoded, compared and classified before a conscious thought emerges. In one sense, once a thought has occurred, the true work of the brain is done and it has moved to another task.

A review of the literature suggests that there is a difference in how the brain reacts to various media. These variations indicate a difference in attention, stress level and ability to concentrate. If the brain has difficulty attending and concentrating on the message, learning is less likely to occur. However, no studies have been done to confirm that the task of reading varies significantly depending on media differences, nor has the research studied brain patterns of subjects' reading ability using various media.

Therefore, this study will explore how media such as print and various computer screens affect the visual processing area of the brain to see if there are differences in attention patterns for reading and what the underlying causes might be. If attention varies because of the medium, it has significant implications for education and distance education in particular, the media and for industry in general.

It will help professionals understand strengths and weaknesses of different media and to use each medium appropriately for delivery of information.

Theory Base

The brain is remarkable. It is incredibly complex, processes huge amounts of information flooding into the body each second, and makes sense of that information to help the organism survive. Through evolutionary processes and thousands of generations, the brain evolves. Simple nervous systems grew into the reptilian brain. The mammalian brain layered on new features such as the limbic system and the primate brain a new layer that allowed for cognition.

As human generations pass, basic brain functions such as processing visual information in the occipital and parietal lobes and the way the brain operates stay the same. But the brain is adaptable and parts of the brain once used for one function have adapted to survival in a different environment, taking on new or modified functions. However, many of the pathways, the interactions within the brain and reactions that the human brain displays are still a function of the biology of the brain.

Theory of Neuronal Group Selection

Many theories describe how the brain processes information, stores memories and develops consciousness. One of the most developed theories is Edelman's Theory of Neuronal Group Selection (TNGS); also referred to as Neural Darwinism (see Edelman 1987, 1989, 1992, 2000, 2004). TNGS has three major components and each will be more fully addressed as the review of literature progresses. The three components are:

1) Developmental Selection. As the brain tissue grows in the embryo there is most certainly constraint based on inheritance and genetic pre-determination for different species. For example, in humans this means development of a brain structure to control or manipulate a hand with an opposable thumb rather than a brain structure to control a wing or flight. It also means that humans "see" a very small, select portion of the electromagnetic spectrum by collecting and processing these very specific energy wavelengths while other animals such as bees have developed the ability to use other wavelengths.

As the brain tissue develops, billions of neurons each extend their myriad branching dendrites. This dendritic structure creates the possibility of incredibly diverse connections in the formation of neural circuits. Some of these connections, such as those connecting the retina of the eye with the visual cortex are quite specific in their connections. Other neuron groups are strengthened later through repeated experiences. These neuron circuits strengthen and weaken their connections according to use and patterns of electrical activity. (Edelman, 2000, p. 82). As Donald Hebb summed up over 50 years ago "Neurons that fire together, wire together." (Hebb, 1949).

In this way and through developmental selection, certain areas of the brain have specialized in handling certain stimuli and functions (Edelman, 2004, p. 17). This research will focus on two of the functional areas of the brain related to sight, the occipital lobes and the parietal lobes.

2) Experiential Selection. Overlapping the developmental period and continuing throughout life, the process of synaptic selection continues to build, based on experiences. As new information is added, new connections and pathways form within clusters of neurons. Neurons within groups and the connections with other nearby neuron groups strengthen and weaken based on use. Conversely, neuron paths that are not used regularly may wither and die. Hubel and Wiesel, in an experiment where they covered one eye of a kitten for several weeks, found that the neurons previously connected to the covered eye had severed those connections and formed new synapses with cells signaling from the unobstructed eye. Not only were new connections being formed by some neurons, those that were no longer being used had grown pale and shrunken and there was evidence of dead or dying neurons after just this short period of time (Czerner 2001, p 138). This experiment, by comparison, serves to illustrate that as new media are introduced into the culture, changes in brain structure will follow through selective experiences and interactions with that medium.

3) Reentry. This is the correlation of events between the related groups of neurons. This allows for each unique individual nervous system to partition an unlabeled world into objects and events. It leads to synchronous activity between neuronal groups and various brain maps and can bind them into circuits. It provides for the integration for the tremendous diversity created in the two selection processes. Reentry helps make sense of the world by combining sensory input from one neuronal group, such as one that recognizes color, and others that classify form. This is not simply a feedback loop that one would find in mechanical systems or in regulation of body systems, as feedback generally involves one system and involves instructions for control and correction. Reentry occurs along many parallel paths, the information is not pre-specified and it can be local (within a group) or global (across groups.)

Theory of Brain Oscillations

This reentry function outlined by Edelman is also explored by Basar (1999) in a two- volume treatise that establishes a brain theory based on neural oscillations. Basar serves as director of the Brain Dynamics Multidisciplinary Research Center and the Department of Biophysics at Dokuz Eyl University, Turkey. He traces the development of this theory over several decades from working with the firing of individual neurons, functional groups of neurons and the brain as an integrated whole and shows the functional significance of the brain's electrical activities. Like Edelman he theorizes that a stimulus input acts to trigger the interaction of masses of neurons, whose interconnections have been determined by previous experience through the mechanism of learning.

This theory recognizes the importance of brain wave oscillations and the functional Electroencephalograms. Electroencephalograms (EEGs) use a series of electrodes placed on the scalp to measure the electrical activity of the brain in the area directly below the electrode. In particular, Basar (1999) outlines how EEGs can be used to detect brain wave frequencies and how these frequencies can be considered as a type of alphabet to decipher brain functions. The EEG consists of the activity of an ensemble of generators producing rhythmic activity in several frequency ranges.

These oscillators are usually intermittently active; however, by the application of sensory stimulation, they are coupled and act together coherently rather than random firing (Basar, 1980).

These wavelike potential changes serve as direct and measurable indices of specific types of brain activity. Brain oscillations can be correlated with multiple functions that include sensory registration and tracking, perception, movement and cognitive processes that are related to attention, learning and memory (Basar, 1999). Perhaps the most important points within this conceptual framework are that the brain is a system for processing and comparing information and that the bioelectrical (EEG) activity recorded from different brain structures is a hot signal and "a real reflection" of brain system functioning. Analysis of the EEG is capable of providing us functional information about the brain and rather than just identifying very specific parts, EEG looks at the overall interactions.

These two bodies of research form the theoretical basis for this study. Edelman indicates that the brain has developed specialized processing areas over a period of time with a combination of biology/evolution and that each individual will have differences based on life experiences as the brain "wires" connections. His work deals with how the brain is "wired" and how it uses the reentry function to have various groups of neurons interact with each other to compare information. Basar's work complements the work of Edelman in the area of reentry and how the brain co-ordinates this information. Basar begins with very basic research on electrical impulses from individual neuron firing and shows how these electrical impulses join together to form the electrical rhythms and oscillations that may coordinate the variety of brain functions.

Brain Waves and Response

Both Edelman and Basar provide a workable model of brain functioning and Basar makes a good case for using EEG's to monitor these brain functions. While the EEG cannot be used specifically to tell what a person is thinking, it can be used to measure attention and measure if a person is thinking by measuring the four general brain wave states:

- Beta waves are defined as brainwaves in the frequency range over 13 waves per second. Beta waves are present in larger numbers during the normal waking/conscious/attending state and would normally be found while reading or processing information—especially on the left side of the brain. The presence of beta waves indicate that the brain is concentrating on a task, especially in the language and math processing areas.
- Alpha waves are a more relaxed state associated with more holistic processing of information in the right brain. They are generally found in alert, but less focused mental states and in meditative, relaxed states. They are defined as occurring in the frequency of 8 to 13 waves per second.
- Theta waves are found in deep relaxation/sleep and occur 4 to 7 waves per second.
- Delta waves indicate deep sleep patterns and loss of conscious attention and are in the frequency range of fewer than 4 waves per second.

The resulting EEG measurements can be linked to specific brain functions. Numerous studies indicate the effects of particular brain wave patterns to attention and cognitive processing. In general, as the waves move from the slow waves of delta/theta to alpha, it signals an increase in awareness. Slow alpha indicates awareness and faster alpha relaxed attention. Beta is found in high levels of attention while performing more challenging information processing activities that involve cognitive load. Some researchers now name the highest levels of beta activity as the gamma rhythm.

Measuring the changes in these patterns reflect what is happening in the subject's information processing situation, even if the subject is unaware of the changes or not able to verbalize what is happening in the processing. Gale (1987) found there is an inverse relationship between alpha power and task difficulty. Horst (1987) also found an abrupt increase in beta activity and blocking of alpha during stress or higher levels of attention. Sterman et al. (1993) evaluated EEG data obtained from 15 Air Force pilots during air refueling and landing exercises performed in an advanced technology aircraft simulator. They found a progressive suppression of 8-12 Hz activity (alpha waves) with increasing amounts of workload. Numerous studies also indicate that learning to suppress theta waves will increase mental performance.

Research in the area of Attention Deficit/Hyperactivity Disorder (ADHD) also indicates that attention and brain wave patterns are linked. Lubar (1991) outlines a 15-year research program to show how students with ADHD can learn through biofeedback to block theta patterns and increase beta activity. As training progresses, attention increases along with grades and improved general behavior in the classroom.

These studies corroborate Basar's theory that brain waves can be used as a measure of neural processing and serve as a measure for levels of attention and processing of information. Use of the EEG also allows measuring attention in a more accurate manner than self-reporting as it can measure pre-conscious information processing.

Defining Attention

Concepts of attention and consciousness have been occupying a central role on how humans perceive themselves and the world around them. Hence literature and theories of attention have been widely used and studied in fields like cognitive psychology and psychophysiology.

According to Lindsley, 1960, attention seems to be contained in "shifting processes and states within the central nervous system, some of which are detectable through changes in electrical potentials recorded indirectly and diffusely from the brain, or directly and focally in certain regions of the brain" (Lindsley, 1960.)

More current definitions contrast a behavioral and cognitive approach:

"Attention is basically an 'orienting' response to a stimulus. It signifies that the stimulus has made contact with a sense organ, such as the eyes or ears of the decision maker, and one or both of the nervous systems, the central nervous system or brain, or the autonomic nervous system, as in purely a 'gut' reaction that may or may not be registered in the brain" (Rossiter and Percy, 1987.) This is a sensory definition of attention.

Contrasting this is a cognitive definition of attention rooted in the information processing paradigm, which define attention as "the allocation of processing capacity to stimuli. That is, attention regulates the amount of additional processing that a stimulus will receive. Generally the more processing capacity that is devoted a stimulus, the greater will be the consumer's awareness and comprehension of it" (Loudon and Della Bitta, 1984.)

Tecce (1972) has provided a working definition of attention as a "process of an organism that facilitates the selection of relevant stimuli from the environment (external or internal) to the exclusion of other stimuli and results in a response to the relevant stimuli" (Andreassi 2000 p. 64.)

This study measures attention in the sensory mode, noting the reaction of the brain in the primary visual processing areas and measure the "response to the relevant stimuli" as defined by Tecce. This definition will be used for this study as it seems to combine both the sensory definition by noting the selection of the stimuli and cognitive definition by noting that the brain has reacted to the stimuli even though it may not be at a conscious level.

Indications of Media Impact

Previous studies have been done that use EEGs to measure media effects, but many of them were done before the widespread use of the computer and focused on television as the medium. Since the brain does not evolve as rapidly as the technology, it must adapt to new technologies. However, some of the previous studies do give us clues to the effects one might expect.

Several studies (Mulholland, Krugman, Emery & Emery) have been conducted showing that humans generally are in a beta state when reading but when they switch to watching TV they move to an alpha state within seconds. This reaction is independent of program content. In addition, metabolism drops to levels lower than those found when staring at a blank wall.

"The evidence is that television not only destroys the capacity of the viewer to attend, it also, by taking over a complex of direct and indirect neural pathways, decreases vigilance--the general state of arousal which prepares the organism for action should its attention be drawn to a specific

stimulus. The continuous trance-like fixation of the TV viewer is then not attention but distraction--a form akin to daydreaming."

From The Emery Report on Television by the Australian National University at Canberra's Center for Continuing Education

These observed actions are in keeping with movement to a lower alpha state. Alert but not focused; eyes scanning the landscape for items of interest; taking in a more holistic image rather than attending to details. This description also is very similar to the descriptions of the ADHD subjects studied by Lubar where children had strong levels of alpha/theta but little beta activity.

Krugman (1970) suggests that it is not the content, but the medium itself is responsible for the brain wave shift to the alpha state. Is the "medium the message" as Marshall McLuhan theorized?

The brain adapts to new inputs and technologies, but there will still be basic hard-wired reactions determined through evolutionary development as outlined in the work of Edelman. Some of these evolutionary artifacts are candidates to explore to understand why attention may differ depending on medium.

One of these artifacts is the effect of light source on mental states. In several studies, Kuller (1992, 1998) and von Bommel (2003), among others, studied the effects of various light sources on brain wave activity. They found significant differences depending on the color and luminance levels. During much of the evolutionary period of humans, there were only two sources of radiant light—the sun/sky and fire. Think about what happens when one gazes at either of these radiant/high luminance sources for a period of time. Generally one finds it relaxing and almost hypnotic. These observations would be in line with an increased alpha state and signal a decrease in beta activity.

Within the last century and with the widespread use of electricity, many more sources of direct radiant light have been developed. With some light sources—devices like computer screens and television sets-- people look directly into them for long periods of time. It is possible that the eye and the brain react differently to radiant light versus reflective light and the differences may show up in human brain wave patterns and emotional responses.

Television and computer monitors are quite similar in how they operate. Both TV and traditional computer screens use Cathode Ray Tubes (CRTs) to project images from a rear gun that shoots electrons onto a phosphor coated screen. This gun passes in a top to bottom pattern and creates a flicker pattern as the phosphors are repeatedly energized and begin to fade and are energized again (TG Publishing, 2005). The phosphors glow and this artificially produced, pulsed light projects directly into the viewer's eye and beyond affecting secretions of our neuro-endocrine system. These screen phosphors give off a light that is skewed toward the blue end of the visible human spectrum. It has been discovered recently that blue tones have especially powerful effects on human circadian rhythms, as blue tones are found toward nightfall, and signal the body to move to a less active state. The most recent studies involving the newly discovered visual receptors in the eye indicate that these signals do not go to the visual processing area at all, but instead go the an area near the pineal and pituitary glands that regulate the circadian rhythm. While these rhythms can not be measured with the EEG used in this study, it is possible they affect the reentry process.

Computer screens are higher definition than television, but both computer monitors and televisions have the rear projection, radiant light—an unusual source for the human eye and brain. And the way the gun "shoots" creates an ongoing flicker that generally one does not perceive at a conscious level, but the flicker still exits on CRT screens but not for LCD screens which use a different technology (TG Publishing, 2005). Studies indicate a similar flicker can exist with fluorescent lighting and studies have shown significant physiological and psychological consequences to varying levels of luminance, flicker and color temperature of the light. In addition, studies have shown that luminance is processed not in the occipital lobes of the brain where most visual forms, colors and object information are processed, but in the parietal lobes where spatial information, luminance and language is processed.

The literature indicates that the source of light, color of light and pulsation may all cause different brain reactions. Various media, such as printed materials, television, computer screens and projected images use a variety of lighting and display techniques. Does the brain, taking in the varied signals from varied media react in different ways to produce differences in attention?

Problem this Research will Address

The studies of television were done before the widespread use of the computer. No current study has determined if the results apply to computer-mediated communication even though the media are similar. The need exists to test between traditional reflective print media, CRT screens that have radiant light and a "flicker", and flat screens that have radiant light and no "flicker".

If physiological factors in the human brain automatically move one from a beta wave state to an alpha wave state (or in some cases to slow wave theta or delta states) depending on lighting and media, it has significant implications for how professionals effectively communicate information. If the findings of reduced attention to television viewing extend to the computer screen it would have serious implications for the design and use of materials used in distance education, in traditional classroom education and for the life-long learning opportunities provided by the various media.

Limitations of This Study

This study is exploratory in nature to see if differences occur in processing information based on the medium. It will use EEG readings from fifteen subjects. Applied Neurosciences Group reports that based on 100 EEG experiments conducted from 1964 to 1994 the average number of subjects for EEG studies ranged from 12 to 20. Having 15 subjects will limit the statistical options available unless normal distributions can be shown for the data. If normal distribution cannot be shown, then less powerful non-parametric tests will have to be used.

As there are documented differences in EEG patterns for "handedness" and for gender (Giannitrapani, 1988), this study will limit the subjects to right-handed females that have no history of brain trauma nor use of mind-altering drugs or medications. In addition, since learning style studies indicate a difference between races for preferred learning styles and some environmental factors such as brightness of lighting on task performance (Sandhu, 1996), Caucasians are used in this study to eliminate any differences based on race. Brain waves also alter with age (Giannitrapani, 1988) and don't show a mature pattern until late teens, so a fairly narrow age range of 18 to 24 will be used. This is a limited and homogeneous subject pool, but one necessary for this experimental design.

To further limit extraneous variables, this study will look at reading only (not other types of visuals) and use black text on white backgrounds.

Due to the exploratory nature and small number of subjects, the significance level will be set at .10. This indicates that the findings will have a 10% chance of being inaccurate simply based on the subject pool and random chance. However, as the research is looking for broad differences in media reaction and there is little physical or mental risk involved to the individual, looking for the broader patterns seems appropriate for this exploratory work.

Purpose of the Study and Research Questions

This study will explore how media such as print and various computer screens affect the visual processing area of the brain to see if there are differences in attention patterns for reading and to see if the differences are due to specific attributes of a particular medium. It will do this through measurement of the brain's response as measured by the brain waves generated while viewing each medium.

The following research questions emerge:

Does the media source, and therefore the source of light, create different brain patterns when reading? Specifically,

1) Does the medium affect the visual processing areas of the brain (occipital and parietal lobes) differently?

2) Do mechanical artifacts, such as flicker, on a CRT screen create different brain patterns in these visual processing areas when reading?

3) If there is a difference, is it due to the flicker effect or radiant lighting versus ambient lighting?

If attention varies because of the medium, it has significant implications for education and distance education in particular, the media and for industry in general. It will help professionals understand strengths and weaknesses of different media and to use each medium appropriately for delivery of information.

CHAPTER TWO • REVIEW OF LITERATURE

Several bodies of literature are applicable to this study. First, several theories of how the brain functions will be discussed. The decade of the 1990's was proclaimed the "decade of the brain" and much significant and varied research was done exploring brain functions. Part of this research explores both the "nature" or biological functioning of the brain and part explores the "nurture" or developmental aspects of the brain. The research shows that various parts of the brain are primarily responsible for processing of visual information and are thought to have distinct functions that will be discussed for the occipital and parietal lobes of the brain. Then the review of literature moves to a specific attribute of the brain: attention and measuring attention through the use of brain wave oscillation patterns as measured through electroencephalograms (EEG). These brain waves are considered by some researchers to be the "alphabet of the brain" and can be used to determine global brain functioning and more global states of information processing. Throughout the review of literature, visual processing through the two primary visual areas of the brain, the occipital and posterior parietal lobes is explored.

The second section of the review deals with the effects of light and media on the human brain. These technologies have been found to affect attention levels and measuring their effect on the brain processes is the focus of this study.

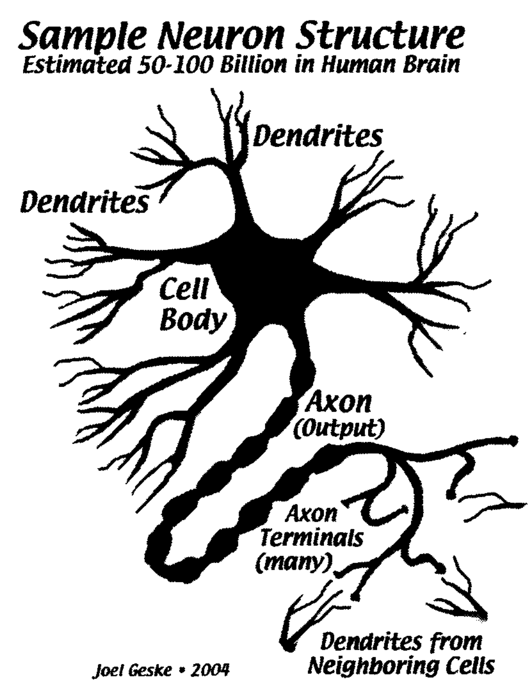
Because of the diverse nature of the literature across many disciplines, major studies that encompass a broad view of the field will be the main focus of the review of literature.

Theory of the Brain

There have been many theories describing how the brain processes information, stores memories and develops consciousness. One of the most developed is Edelman's Theory of Neuronal Group Selection (TNGS) which is also referred to as Neural Darwinism (see Edelman 1987, 1989, 1992, 2000, 2004). This theory has applications to this study by providing a basic understanding of how the brain processes information. While not dealing specifically with attention, it provides a framework for understanding brain functions that will be important for the study.

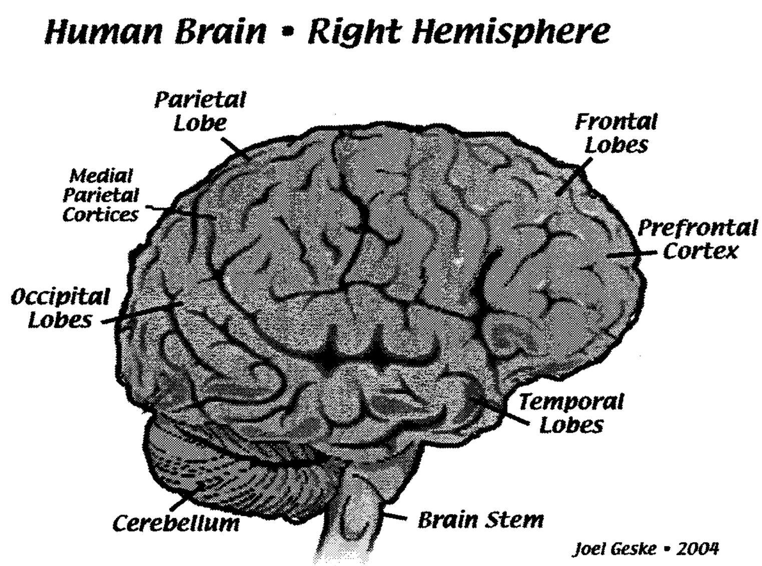
TNGS has three major components and each will be more fully addressed as the review of literature progresses. The three components are:

1) Developmental Selection. As the brain tissue grows in the embryo there is most certainly constraint based on inheritance and genetic pre-determination for different species. For example, in humans this means development in the brain to control or manipulate a hand with an opposable thumb rather than the brain structure to control a wing or flight. It means that we "see" a very small, select portion of the electromagnetic spectrum by collecting and processing these very specific energy wavelengths while other animals such as bees have developed the ability to use other wavelengths. As the brain tissue develops, billions of neurons each extend their myriad branching dendrites. This dendritic structure creates the possibility of incredibly diverse connections in the formation of neural circuits. Some of these connections, such as those connecting the retina of the eye with the visual cortex are quite specific in their connections. Other neuron groups are strengthened later through repeated experiences. These neuron circuits strengthen and weaken their connections according to use and patterns of electrical activity. (Edelman, 2000, p. 82). As Donald Hebb summed up over 50 years ago "Neurons that fire together, wire together." (Hebb, 1949). Although the neurons never actually fuse or connect, the number of transmitters and receptors actually increase to make the connection stronger, or are pruned to make



the connection weaker. This idea from long ago has been confirmed through more modern tracking systems and this forms the basis of TNGS. These more strongly associated neurons that fire together are more closely connected to one another than to neurons in other groups or clusters. In this way and through developmental selection, certain areas of the brain have specialized in handling certain stimuli and functions (Edelman, 2004, p. 17).

The sight and visual areas have been particularly well documented. This research will focus on two of these functional areas of the brain related to sight, the occipital lobes and the parietal lobes located at the posterior and top of the brain as seen in the illustration.



2) Experiential Selection. Overlapping this developmental period and continuing throughout life, this process of synaptic selection continues to build, based on experiences. As new information is added, new connections form within these clusters of neurons. Neurons within groups and connections with other nearby groups strengthen and weaken based on use. Recalling from chapter one the example of primitive woman: through trial and error, the neuron grouping we label as "red" became associated with berries that were ready to eat or tasted the best. When the eye registered the qualia of red with the shape and form of a specific berry, the neuronal groups firing together would activate a memory that indicated that this berry could be eaten. This would trigger a complex mechanical movement to pick the berry. After a period of time, these associational neuron group firings and motions would become so strong that the action would seem automatic and would perhaps no longer register in conscious thought.

Strength of connections builds through time (or can form an immediate strong bond if there are strong emotional connections). Conversely, neuron paths that are not used regularly may be "pruned" or wither and die. Hubel and Wiesel, in an experiment where they covered one eye of a kitten for several weeks, found that the neurons previously connected to the covered eye had severed those connections and formed new synapses with cells signaling from the unobstructed eye. Not only were new connections being formed by some neurons, those that were no longer being used had grown pale and shrunken and there was evidence of dead or dying neurons after just this short period of time (Czerner 2001, p 138).

3) Reentry. This is the correlation of events between the related groups of neurons. This allows for each unique individual nervous system to partition an unlabeled world into objects and events. It leads to synchronous activity between neuronal groups and various brain maps and can bind them into circuits. It provides for the integration for the tremendous diversity created in the two selection processes. It is the process of reentry that helps make sense of the world. It helps combine sensory input from one neuronal group, such as one that recognizes color, and others that classify form. This is not simply a feedback loop that one would find in mechanical systems or in regulation of body systems as feedback generally involves one system and involves instructions for control and correction. Reentry occurs along many parallel paths and the information is not pre-specified and it can be local (within a group) or global (across groups.)

One property of conscious thought is that it is unitary or integrated in healthy individuals (Edelman, 2004, p. 7). He uses the example of writing. While writing, one may be focused on the act of writing, but also aware of the sunlight coming in the window, background noises, and the hardness of the chair one is sitting on. This "fringe" state of awareness is constantly changing, but rarely can be ignored entirely to focus on just one aspect. It contains many different elements—sensations, perceptions, images, memories, thoughts, emotions, physical aches and pains, vague feelings, etc. At any moment, all past experiences engage to form an integrated awareness of each single moment and is very individual. (Edelman, 2004, p. 8)

Instead of being guided by a set of procedures as a computer would, the brain is guided by a structure, which means that activities arise by selection and comparison rather than by rules of logic found in a computer. It is this selection process that has given rise to language and art and it is selection, not logic, that gives humans pattern recognition and thinking in metaphorical terms. This is not to say that the brain can't learn to use sets of rules that lead to logical thinking. It does indicate that the structural selection process is the more basic and innate system that has developed in biological systems. Edelman concludes that it appears there are only these two deeply fundamental ways to pattern thought--selectionism and logic—with selectionism the biologically more fundamental process. (Edelman 2000, p. 214).

These human physiological attributes developed over many millennia and while evolution continues, it is a very slow process. The brain itself does not change significantly in its genetic/biological structure and hardwired, genetically coded pathways and responses still remain. For example, as humans evolved various patterns of thinking and brain wave patterns based on their hunter/gatherer development also evolved. Recent studies on Attention Deficit Disorder (ADD) in young men indicate that ADD should probably not be classified as a "disease or affliction" but that the men are at one end of a continuum of normal brain wave patterns that would indicate a "gatherer" heritage. In this pattern, the brain waves are such that the eye scans for items of interest, but does not focus or attend to individual tasks for long periods of time. The individual with ADD simply has a specific set of brain wave patterns consistent with evolution and not necessarily in synch with modern expectations of attending in certain cognitive areas such as school work. The subject may excel and be able to attend to other tasks, such as video games, that require the brain wave patterns more in tune with those found in subjects with ADD. This will be covered in more detail as individual brain wave patterns are discussed.

In a second example, based on our gatherer evolution, humans have been "programmed" to notice certain stimuli and combinations of forms and colors to form associations. Red berries or yellowing fruit are seen as ripe, edible food, and today in the supermarket consumers gather red boxes of frozen dinners and yellow boxes of cereal. Color is "a very powerful tool," notes Eric Johnson, head of Research Studies for the Chicago-based Institute for Color Research, which collects scientific information about the human response to color. Red stimulates feelings of arousal and appetite. Indeed, when the eye sees red, the pituitary gland sends out signals that make the heart beat faster, the blood pressure increase, and the muscles tense—all physiologic changes that can lead to the consummation of a purchase (Tufts, 1999).

There are other examples, but it is reasonably well documented that our physical evolution continues to impact our brain patterns and behaviors. All new communication technologies, from movable type forward, are but a blip on the evolutionary scale. While we may have adapted to the technologies, there still are most likely evolutionary byproducts embedded in how we perceive and process them.

The brain is very specific in this information processing. Edelman's Theory of Neuronal Group Selection has helped us understand how the brain forms neural pathways, clusters, and areas to process information. We know that there are neurons or small groups of neurons that are VERY specific in their response to stimuli. In some cases a specific neuron will only fire if a line is at a particular angle or a color is a particular wavelength of light. In his book A Vision of the Brain, Zeki explains in detail how the visual areas of the brain process this information. As the TNGS proposes, these individual neurons join together to form networks and these networks interact to form images, memories and conscious thought.

The brain adapts to new inputs and technologies, but for the purposes of this research, it is accepted that depending on the type of input, such as still or motion, color or B&W, radiant or reflective, the sensory input is going to be processed by different neuron groups and cause different physical and emotional reactions. For example, consider one factor of visual stimuli, luminance. Eyes and sight developed using mostly ambient or reflected light rather than radiant or direct light. Ambient light is what humans use in everyday seeing---watching the grasses or shadows for a predator, scanning the landscape for food, attending to the teacher in school or reading a favorite book or magazine.

During much of the evolutionary period of humans, there were only two sources of radiant light—the sun/sky and fire. Think about what happens when an individual lies back and looks up at the sky (maybe with clouds) for a period of time.....one starts relaxing and seeing shapes in the clouds and generally moves into kind of a dreamy state. What happens when one gazes at a fire source for a period of time...a flickering candle or campfire? Generally one finds it relaxing and this effect can be used to set emotional moods. Within the last century, many more sources of direct radiant light (some with the addition of flickering) have been developed and some forms people look directly into for long periods of time--things like computer screens and television sets. The eye and the brain may react differently to radiant light versus reflective light and the differences appear to show up in human brain wave patterns and neurological responses.

Occipital and Parietal Lobe Functions

As indicated by the Theory of Neuronal Group Selection, these differences in luminance, source of light and color of the light will all impact where the information is processed in the brain, the neuron firing patterns, the brain wave patterns of the subject and the resulting attention levels. These component waves can be used as the dependent variable to measure attention and loss of attention.

Visual stimuli are processed in two distinct areas of brain, the occipital lobes located at the back lower portion of the cortex and the parietal lobes located directly above the occipital area and proceeding toward the top of the cortex. The function of the posterior parietal cortex has been debated since the 19th century. Early studies indicated it was an "association area" where different senses were integrated. Mountcastle (1975), working with monkeys found that single neurons in this area were correlated with behavior or movements such as reaching, eye fixation, eye saccades and pursuit eye movements and from this proposed that the posterior parietal cortex was involved in directing motor behaviors. This concept was challenged by Robinson and Goldberg (1978) and Goldberg and Bushnell (1981) who found similar results but interpreted it as being related to attention processes rather than motor processes. This work led to breakthrough work by Ungerleider and Mishkin (1982) showing that there are two pathways in the visual stream, the ventral pathway that leads to objects recognition and the dorsal pathway that provides spatial perception.

The ventral stream leads to the occipital lobes to process object identification and color (sometimes named the "what" stream) and dorsal stream leads to the posterior portion of the parietal lobes to process luminance leading to three-dimensional rendering and spatial information. While there is not a clear dividing line between the occipital and parietal lobes (Parent, 1996), the international standard for electrode placement will be used for occipital and parietal electrode placements. It is important that both of these areas of the brain be sampled separately to see if and how the dorsal and ventral stream process media information differently. Many previous studies treat these two areas as one visual processing unit.

It is known that the parietal lobes process space recognition and spatial information in the right hemisphere with body image and language on the left (LeMay, 1976; Falk 1991). The caudal or posterior sections receive direct and indirect information from the primary visual cortex with the remaining section is involved in senso-motor activity. These lobes allow us to place objects in space and coordinate movement appropriately to approach, reach or grasp (Glickstein, 2003). In particular, the parietal lobes are increasingly considered at the interface between perception and action (Macaluso and Driver, 2003). The parietal lobes have been well-studied in monkeys and the research supports the role of the superior parietal lobes in attention, space recognition and visual approach. (For a complete review of the role of the parietal lobes in attention, visual processing and visual integrations, see Colvin, Handy and Gazzaniga, 2003.)

The parietal lobes also have a particular role in directing eye movement and focusing attention. Therefore, for the purposes of this study, it is important to note that the occipital lobes and parietal lobes both play important and distinct roles in visual processing and language recognition and will therefore be examined separately.

Neural Oscillations as a "Language of the Brain"

Basar (1999) in a two-volume treatise, establishes a brain theory based on neural oscillations. He traces the development of this theory over several decades from working with the firing of individual neurons, functional groups of neurons and the brain as an integrated whole and shows the functional significance of the brain's electrical activities. Like Edelman he theorizes that a stimulus input acts to trigger the interaction of masses of neurons, whose interconnections have been determined by previous experience through the mechanism of learning.

Basar now asserts that brain scientists have recognized the importance of oscillatory phenomena and the functional EEG, which will probably create the basic approach for a biophysical understanding of the brain machinery. In particular, he outlines how Electroencephalograms (EEG's) can be used to detect brain wave frequencies and how these frequencies can be considered as a type of alphabet for brain functions. The EEG consists of the activity of an ensemble of generators producing rhythmic activity in several frequency ranges. These oscillators are usually randomly active; however, by the application of sensory stimulation, they are coupled and act together coherently. This synchronization and enhancement of EEG activity gives rise to an evoked or induced rhythmicity. (Basar 1980).

He proposes that the EEG is not simply a noise, but that it is in all probability one of the most useful signals of the brain related to evoked potentials (EP). These rhythmicities may also occur without defined physical stimulation but may be triggered by hidden sources, for example, as a result of cognitive loading. In other words…coherent EEG states are considered internally induced rhythmicities, similar to EPs but without known causal events. He uses the terms such as "alpha response" and "theta response" to describe these brain wave patterns.

The alpha response is considered a resting brain state and is most often found strongly in the occipital and parietal lobe areas of the brain. In the brain there is almost always background firing of neurons. Coding is superimposed on this background of incessant, irregular discharge. The same kind of neurons are organized together, receiving the same kinds of messages on the whole and transmitting the same kind of coded input to another cluster of neurons. Because of the incessant background noise, the responses of one neuron are lost but when they group together the signal is strong enough to be "heard." In other words, the neurons have to "shout together", as it were, to get the message across and so make a reliable signal despite all the background noise (Basar, 1999).

One of the most reliable findings in EEG research is phenomenon of alpha blocking. Alpha rhythm is blocked when the eyes are opened, there is alert attention or mental activity such as solving a mental arithmetic problem (Basar, 1999). Basar does indicate that in some cases an adult might not exhibit an alpha rhythm, but this is rare. In a study of 12 subjects, Mulholland and Peper (1971) found that alpha blocking occurred every time in subjects doing various tracking and blur/focus tasks. Subjects could be trained to not follow the stimuli motion and "blur" the vision to not produce the alpha blocking response. However, in all untrained subjects the alpha blocking did occur when the eye were opened and active in tracking or focusing. Therefore, the alpha block has been found to be an effective method of noting attention, although Mulholland suggests the attention is actually a measure of tracking eye movement and changes in the visual control systems.

Basar (1999) proposes these wavelike potential changes serve as direct and measurable indices of brain activity. Based on the results, brain oscillations can be correlated with multiple functions that include sensory registration and tracking, perception, movement and cognitive processes that are related to attention, learning and memory. Perhaps the most important points within this conceptual framework are that the brain is a system for processing and comparing information and that the bioelectrical (EEG) activity recorded from different brain structures is a hot signal and "a real reflection" of brain system functioning. Analysis of the EEG is capable of providing us functional information about the brain.

The brain, in these two theoretical perspectives outlined by Edelman and Basar, does not just represent the features of an object that provides the source of sensory stimulation. The stimulus input acts to trigger the interaction of masses of neurons, whose interconnections have been established partly by genetics and modified by previous experience. It compares the new information to existing firing patterns learned through previous behavior and constructs the significance of the input for the behavior of the organism. The key new concept is the hierarchical organization of the neurons with each other to form assemblies, then of assemblies to form brains, then of brains to cause muscles to move the organism into the surrounding environment. Basar concludes this controls the relations of the sensory receptors to the world and enables brains to select their own input and adapt it to their own purposes. (Basar,Volume 2 p XI)

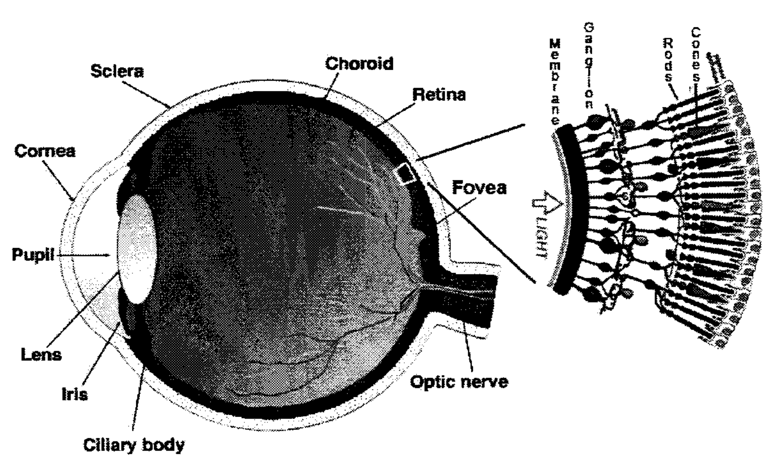
These theories form the basis for this research project to explore if the brain reacts differently to different media stimuli in such a way as to affect the attention and processing of information in meaningful way for the organism. The work by Edelman helps us understand how the human brain has evolved and how developmental selection creates specific areas of the brain for specific functions. This developmental selection is overlaid with experiential selection and the research shows that there may be tremendous variation between individuals in neuronal group patterns that lead to the same general output. This is based on individual differences in experiences, neuronal connections and reentry patterns from other neuron groups in associated areas. These differences will have to be taken into account for the study. The work by various researchers indicates both the ventral and dorsal visual processing streams need to be looked at for potential differences. The ventral stream needs to be considered to see if there are differences indicated in how objects are perceived or processed in terms of line, shape or form. Differences in the dorsal or parietal stream would indicate that there are differences in eye movement, spatial processing and focus of attention. Basar indicates that brain oscillations measured by the EEG can be correlated with multiple functions that include sensory registration and tracking, perception, movement and cognitive processes that are related to attention, learning and memory.

Previous research indicates that some media may cause the brain to react with distinctive EEG patterns, reflecting specific neuronal group firings, to inhibit attention and effective processing of information. Marshall McLuhan, in an often quoted statement, said "The medium is the message." Decades later, it may be that the scientific understanding of brain waves will show this to be true. The delivery method may indeed be providing the message based on the brain areas stimulated and the wave pattern generated. One of the key areas to explore in media differences is the effect of light.

Visual Stimuli and the Effects of Light

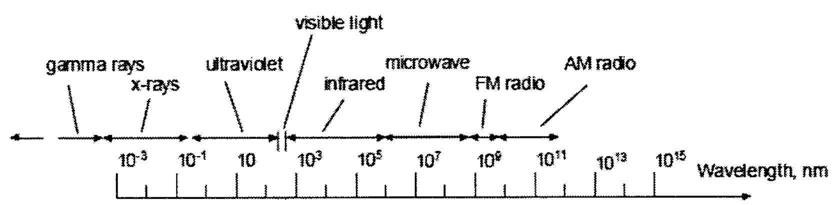
The brain is enclosed inside the dark, bony skull and relies on the many stimuli that enter the body through the five senses that have developed in humans. This research explores visual stimuli and will limit discussion to that particular sense.

Processing of visual stimuli begins with the eye. The figure below shows a cross section schematic human eyeball. The front section of the eyeball contains the eye's optical system with the cornea, lens, and iris. The space between the cornea and lens is filled with a fluid known as the aqueous humor and the central cavity of the eye is filled with a thick fluid known as the vitreous.



Side View of Human Eye with Retina Enlargement
Source: Modified from http://webvision.med.utah.edu/imageswv/Sagschem.jpeg

The eye's interior back section has three layers with the retina layer the main processor of light stimuli. The retina is composed of two major classes of photoreceptor cells known as the rods and cones because of their shapes. Each retina has approximately 100 to 120 million rods and 7 to 8 million cones. The rods are extremely sensitive to light and provide non-color vision at low (scotopic) illumination levels. The cones require more light to be activated than the rods but provide color vision at high light (photopic) levels. Light striking the retina must first pass through several layers of neural tissue before reaching the photoreceptors. Only in one very small area named the fovea are the photoreceptive surfaces directly exposed to light (see diagram)

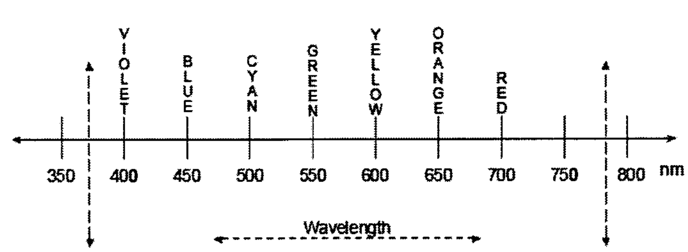


Electromagnetic Spectrum

The rod and cone systems are sensitive to light wavelengths from approximately 400 to 700 nanometers (nm) of the electromagnetic spectrum.

The rods have their peak sensitivity at about 498nm, and are very sensitive to even low levels of light. In fact, even one photon striking a rod can trigger a neuronal response (Cerner, 2001).

The three types of cones each react to a specific wavelength range. The short wavelength or "blue" cones have their peak response at 420 nm, the medium wavelength or "green" cones peak at 534 nm, and the long wavelength or "red" cones peak at 564 nm. Significant overlap exists between the response ranges of the different cones, so one stimulus may cause several cone types to react. The rods and cones aren't distributed evenly over retina.



Human Visible Spectrum

The fovea, which is the primary focal point in the eye has the most dense concentration of cones but nearly no rods. Cones extend outward, falling off in density until about 20 degrees from the fovea. Rods become increasingly dense in these peripheral areas out to about 80 degrees. (Ferwerda, 2001)

Over the past few years, researchers have also discovered a third photo-receptive source in the eye that appears to control the circadian rhythm and melatonin/serotonin production. Melatonin is a sleep hormone that is produced in the pineal gland from metabolism of serotonin. Melatonin's production is stimulated by darkness, and it is important for the induction and maintenance of sleep (Jan, et al. 1996).

In tests of seventy-two 24-year-old subjects, Brainard found that specific light frequencies, in particular 446-477 nm (blue), as the most potent wavelength region providing circadian input for regulating melatonin secretion. The results suggest that, in humans, a single photopigment may be primarily responsible for melatonin regulation, and its peak absorbance appears to be distinct from that of rod and cone cell photopigments for vision (Brainard 2001).

In another study, done with mice, Edelstein and Mrosovsky found light has rapid direct effects on behavior and physiology that may be distinguished from its indirect effects that occur via synchronization of the biological clock. These findings support the view that masking effects of light on behavior comprise two opposing processes, one that increases activity and is mediated by the classical visual system, and another that suppresses activity and is mediated by a non image-forming irradiance detection system (Edelstein and Mrosovsky, 2001). In general, the systems work to balance one another.

In 2002, Berson and colleagues announced finding the source of this irradiance detection system deep in the retina of the eye of mice. These melanopsin-containing retinal ganglion cells (RGCs) are intrinsically light sensitive, and project to the brain's "master clock," (Roberts, 2004).

Those seeking the roots of melanopsin's influence on circadian rhythms say the research could profoundly affect the understanding of human health. "Much of our physiology is being modified by environmental brightness," says Foster. The circadian clock influences not just sleep cycles, but hormonal release, mood, alertness, cognitive performance, and activity level (Roberts, 2004).

In mammals, including humans, the biological clock resides in a group of neuron clusters in the hypothalamus, a brain region that responds to many chemical inputs, including the hormone melatonin, which is derived from the metabolism of serotonin. Melatonin is secreted by another hypothalamic brain structure, the pineal gland, which in turn is stimulated by neurons in a nearby cluster (the suprachiasmatic nucleus) that receives input from the retina of the eye. So this is the apparent pathway of light-induced secretion of melatonin and action in mammals: light on the retina, electrical activity in the retino-hypothalamic tract, activity in a hypothalamic region called the suprachiasmatic nucleus, electrical signals to the pineal gland, secretion of the hormone melatonin, action of melatonin on other neural structures in the hypothalamus and elsewhere. (New Engl. J. Med. 2000 343:1070)

While this new receptor and its implications are not directly a subject of this study, it appears that the eye and light input provide not only visual stimuli, but have direct affects on other rhythms and oscillations in the body as well. Edelman's theory indicates extensive reentry functions between brain areas and the color and type of the light source could be a factor. Eysel suggests that the effects of light (and flicker in particular) can extend beyond the visual processing area to affect the brain and brain oscillations on a more global level.

Rhythmic phenomena represent one of the most striking manifestations of dynamic behavior in biological systems. In 1936, Fessard published a book on the Rhythmic Properties of Living Matter. This book was devoted solely to the oscillatory properties of nerve cells, but it is now clear that rhythms are encountered at all levels of biological organization, with periods ranging from a fraction of a second to years. These rhythms find their roots in the many regulatory mechanisms that control the dynamics of living systems. Thus, at the cellular level, neural and cardiac rhythms are associated with the regulation of voltage-dependent ion channels, metabolic oscillations originate from the regulation of enzyme activity, pulsatile intercellular signals and intracellular calcium oscillations involve the control of receptor activity or transport processes, while regulation of gene expression underlies circadian rhythms. In summary: oscillations arise in genetic and metabolic networks as a result of various modes of cellular regulation. (Goldbeter, 2002).

These studies indicate that light has a distinct effect on brain functions, not limited to vision. The nature of the light and the wavelength of the electromagnetism may have effects on both visual and non-visual processing of this light energy. In particular, Edelstein's indication of a non image-forming irradiance detection system that focuses on the blue end of the electromagnetic spectrum may be of importance as this research considers various media and information delivery methods. It becomes obvious from the literature that the brain and body operate as a series of rhythms that affect both physiological and psychological behaviors.

The Nature of Brain Oscillations

The electrical activity in the brain generates at least four distinct brain wave patterns, although some researchers break out a fifth pattern as well.

Alpha Rhythm

The alpha rhythm is the predominant EEG wave pattern and is found when adults are awake with the eyes closed. Generally this state is referred to as the baseline. Different areas of the brain are more likely to generate a particular wave forms, and the alpha rhythm is most likely to occur in the occipital regions and parietal lobes important to this research. Alpha waves normally are recorded in the 8-13 cycles per second range (referred to as hertz or hz) and have an amplitude ranging from 20 to 200 micro-volts (mV). These are relatively high amplitudes but it must be noted that the EEG measures total brain activity and positive and negative waves can cancel out. This higher amplitude indicates overall activity with few cluster firings of neurons. As attention increases, the overall amplitude has a tendency to decrease below the 20 mV range.

Wave patterns are quite individual, but in general women have higher mean frequencies than men; outgoing individuals have higher frequencies; and frequencies can vary depending on the mental exercises being performed with the eyes closed. For these reasons, there is no standard or average alpha baseline for the general population or to use as a control. The resting alpha state for each individual will need to serve as the baseline and changes in brain activity will be measured against the resting or baseline alpha. Generally, slower frequency alpha rhythms in the 8 to 10 hz range indicate a more relaxed state associated with more holistic processing of information in the right brain and are generally found in alert, but less focused mental states and in meditative, relaxed states. Information is being taken in, but not processed in as linear a fashion, but more holistically in impressions and patterns. Higher frequency alpha in the 10 to 12 hz range are generally associated with relaxed attention and not actively engaged in difficult cognitive tasks.

Beta Waves

Beta waves are present in larger numbers during the normal waking/conscious/attending state and would normally be found while reading or processing information. Beta waves normally are recorded in the 14 to 30 hz range and have a much smaller amplitude ranging from 5 to 10 uV. Attention deficit disorder (ADD) research and other studies show this brain pattern is linked to attention. Subjects clinically diagnosed with ADD show a very little beta wave activity.

Gamma Waves

Some researchers refer to beta waves above the 30 hz range as gamma. The higher the frequency, the more intense the attention and brain processing levels.

Theta Waves

Theta waves are found in deep relaxation/sleep and the alpha/theta border is considered a wave pattern during which the subject exhibits high levels of creativity. ADD patients generally have a greater abundance of theta activity than the average population.

Delta Waves

Delta waves indicate sleep patterns and a loss of consciousness. They will be present in waking states, but an increase in delta patterns generally indicate a move toward drowsiness and sleep and away from attention and active processing of information.

Brain Waves and Attention

Basar postulates that brain waves and the resulting EEG measurements can be linked to specific brain functions. Numerous studies indicate the effects of particular brain wave patterns to attention and cognitive processing:

- The generalized effect of stress, activation or attention produces a shift towards the faster frequencies, lower amplitudes (beta) with an abrupt blocking of alpha activity (Horst, 1987).
- Sterman et al. (1993) evaluated EEG data obtained from 15 Air Force pilots during air refueling and landing exercises performed in an advanced technology aircraft simulator. They found a progressive suppression of 8-12 Hz activity (alpha waves) at parietal sites with increasing amounts of workload.
- There is in inverse relationship between alpha power and task difficulty (Gale, 1987).

Other studies have also demonstrated the sensitivity of alpha waves to variations in workload associated with task performance.

- Natani and Gomer (1981) found decreased alpha and theta power when high workload conditions were introduced to pilots during pitch and roll disturbances in flight.
- Studies have also demonstrated that theta may be sensitive to increases in mental workload. Subjects have been trained to produce EEG theta patterns to regulate degrees of attention (Beatty, Greenberg, Diebler, & O'Hanlon, 1974; Beatty & O'Hanlon, 1979; O'Hanlon & Beatty, 1979; O'Hanlon, Royal, & Beatty, 1977). In particular, Beatty and O'Hanlon (1979) found that both college students and trained radar operators, who had been taught to suppress theta activity performed better than controls on a vigilance task.

• Though theta regulation has been shown to affect attention, the magnitude of the effect is often small (Alluisi, Coates, & Morgan, 1977).

• More recent research, however, has demonstrated its utility in assessing mental workload. Both Natani and Gomer (1981) and Sirevaag, Kramer, deJong, and Mecklinger (1988) found decreases in theta activity as task difficulty increased and during transitions from single to multiple tasks, respectively.

Basar's theory is also corroborated by recent studies involving young men diagnosed with Attention Deficit Disorder (ADD). EEG biofeedback has emerged as a viable method for treating ADD by allowing the brain to learn how to alter particular EEG rhythms and to control the relationships between them. The origins of EEG biofeedback for ADD/ADHD are found in neurodiagnostic work that was pioneered by Jasper and Knott, but was not fully pursued until the 1970's. In particular, Satterfield et. al. (1973) developed the hypothesis that hyperkinetic children have a problem with reticular activation, resulting in a low level of arousal, so that these children are easily habituated to sensory stimulation.

More extensive studies (Lubar, 1977; Shouse & Lubar, 1978, 1979) followed, employing more children. These blind studies provided clear evidence that EEG training was a useful modality for working with the hyperkinetic disorder. After completing these controlled studies, Lubar began to use EEG biofeedback training with hyperkinetic children, as well as patients with seizure disorders. He found that children with attention difficulties and problems in reading or spelling, who were not hyperkinetic, exhibited excessive 4-8 Hz theta, plus were deficient in beta production. He developed a program that involved training of beta (16-20 Hz) activity and theta was inhibited.

A case study of six such patients showed that training--particularly encouragement of beta and reduction of theta waves--produced significant and sustained improvements in school performance and psychometric measures. Letter grades improved, and learning curves showed significant improvements. When the training was reversed to previous patterns, grades and classroom activity deteriorated. When training was restored, grades and performance again increased. (Lubar outlines this 15 year research program in a 1991 article in Biofeedback and Regulation, pp. 201- 225). Gains can be permanent, particularly if the biofeedback skills are combined with academic training and incorporated into the classroom setting. Children can build on what they have achieved, and continue to do better.

There is indication that media may affect brain wave patterns and physiologic responses as well and actually produce brain wave patterns similar to those seen in ADD patients. Several studies (Mulholland, Krugman, Emery & Emery) show that humans are in a beta state when reading but when they switch to watching TV they move to an alpha state within 30 seconds. This is independent of program content. In addition, metabolism drops to levels lower than found staring at a blank wall.

> *"The evidence is that television not only destroys the capacity of the viewer to attend, it also, by taking over a complex of direct and indirect neural pathways, decreases vigilance--the general state of arousal which prepares the organism for action should its attention be drawn to a specific stimulus. The continuous trance-like fixation of the TV viewer is then not attention but distraction--a form akin to daydreaming."*
>
> ***From The Emery Report on Television by the Australian National University at Canberra's Center for Continuing Education***

One can conclude that television appears to cause human subjects to move from an attentive beta processing state to a more holistic and unfocused alpha processing state. Krugman's study found that this movement happens within seconds. Some caution is required as the Krugman study was done in the 1960's using a simulated television screen and used a single subject. However, the later studies do have similar findings.

Light, Luminance and Flicker

Moving forward in time with the introduction of a newer technology, one finds the standard personal computer monitors and televisions are quite similar. Both TV and traditional computer screens use Cathode Ray Tubes (CRT) to project a stream of electrons from a rear mounted gun onto a phosphor-coated screen. The gun starts at the top corner of the screen and sweeps back and forth in linear patterns to shoot the electrons at the phosphor dots or pixels. The electron stream excites the phosphor and it emits light. Over a short period of time, the phosphor loses it luminance until the electron gun scans past again with a new burst of energy. Depending on the device, this scan time may vary slightly, but is generally about 25 to 30 Hz meaning that the screen refreshes from top to bottom 30 times per second. This causes a slight "flicker" effect that is more noticeable in some devices and to some people than others. Improvements in technology by the time computer CRTs emerged allow for higher refresh rates nearly double televisions to reduce flicker, but the same electron stream, phosphor coating and backlighting techniques are used. CRT screens using a 60 hz refresh rate have a visible flickering that is greatly reduced when set to 75 hz. (TG Publishing, 2005).

Studies indicate the type of lighting can make significant difference in physiologic response, mood and attention. A study done by Phillips Lighting shows some people experience headaches because of the light ripple caused by the 50 hz power supply of fluorescent lamps operated on older magnetic ballasts. Fluorescent lamps running on modern, high-frequency electronic ballasts operate at around 30 kHz and thus do not exhibit this flicker or ripple phenomenon. In a comparison, it has been found that the occurrence of headache is, indeed, significantly lower when electronic ballasts are used (Wilkens, 1989). Küller and Laike measured the EEG of persons working in an office environment under respectively magnetic (50 Hz) and high-frequency fluorescent lighting. At the same time, they also measured the speed and errors made in a proof-reading task. Their results show that the reciprocal value of the alpha activity of the EEG, and therefore the brain arousal ("stress"), is higher with the 50 Hz operated lighting. The working speed is slightly higher, but the errors are dramatically higher (more than double). The combined effect means that it is wise, from both the well-being and productivity points of view, to use high-frequency fluorescent lighting instead of magnetic 50 Hz lighting to limit brain arousal or stress. For this study, this could indicate that it could be the quality of the light or the 50Hz "flicker" that causes the changes in brain activity noted in television viewing.

For computer screens, this artificially produced, pulsed light projects directly into our eyes and beyond affecting brain functions and perhaps secretions of our neuro-endocrine system. The computer screens are higher definition than television, but both have the rear projection, radiant light—an unusual source for the human eye and brain. And the way the gun "shoots" creates a ongoing flicker that generally we can't see at a conscious level, but still exits. A similar situation can exist with fluorescent lighting and studies have shown significant physiological and psychological consequences.

These phosphors give off a light that is skewed toward the blue end of the visible human spectrum. It has been discovered recently that these blue tones have especially powerful effects on human circadian rhythms. In a technical report by Phillips Lighting, von Bommel notes, "By comparing the (data) it is immediately evident that the biological sensitivity for different wavelengths of light is quite different from the visual sensitivity. Where the maximum visual sensitivity lies in the yellow-green wavelength region, maximum biological sensitivity lies in the blue region of the spectrum. These phenomena have an important meaning for the specification of healthy lighting."

Kuller (1998) also conducted studies on general office lighting and measured EEG's. These findings indicate that daylight tubes caused more visual discomfort, especially at high luminance and fluorescent tubes at high luminance cause arousal of the central nervous system, especially if those tubes are of the 'Daylight' kind. These studies indicate that lighting, in general, can have biological effects on the EEG patterns and attention patterns in humans. Luminance becomes one possible factor in differences between media to be tested.

The studies of television were done before the widespread use of the computer. No current study has determined if the results apply to computer-mediated communication. The need exists to test between traditional reflective print media, CRT screens that have radiant light and a "flicker," and flat screens that have radiant light and no "flicker."

If physiologic factors in the human brain automatically move one from a beta wave state to an alpha wave state (or in some cases a sleep-inducing delta state) depending on lighting and media, it has significant implications for how we effectively communicate information and for computer-mediated education.

Summary

This review of a diverse body of literature brings together numerous points that indicate more research needs to be conducted on how the physical aspects of various media influence our brain wave patterns and hence ability to attend. There is evidence that the brain reacts differently to different light sources, ambient and radiant. Some studies show that blue light in particular may be a factor in setting biological clocks and oscillations in the brain, which could affect attention. The CRT screens of television and computer monitors emit light from the phosphor coats with a definite blue tone and emit other non-visible waves. There is some limited research indicating that these non-visible electromagnetic waves also have an effect on production of melatonin and other systems of the brain. Other factors such as electromagnetic frequency and cycling or flickering of those light sources may also be important. Several studies of television viewing confirm that looking at the television screen decreases attention regardless of program content (Krugman, 1971). This would indicate that it is something in the mechanics of the medium, not in the processing of the information, that is causing the brain wave shift.

Basar, in his extensive work on brain function, makes a good case that brain oscillations are the "alphabet" of the brain and an important way to find out how various areas of the brain are interacting. Recent studies of subjects with ADD also relate brain oscillations and the lack of beta activity with lack of attending to information. The studies on the effects of light on physical body rhythms also points out the importance of the interaction of numerous physical oscillations, including brain waves.

Therefore, this study proposes to measure the brain wave activity of subjects while reading from various media through the use of electroencephalograms (EEG's). Because of the complexity of brain and processing of information, this study will be limited to the function of reading and will measure simple black text. This will limit the potential for confounding variables of color, motion, and emotional involvement with a visual image. While these will all be important areas for future study, it is beyond the scope of this work, which will focus on the response to light and media for reading text.

Based on previous studies, it will be important to measure both the occipital and parietal lobes separately, not as one visual processing unit as luminance is processed in the parietal lobes. However, as Edelman suggests, there will most likely be considerable individual variation based on individual past experiences and reentry patterns so the research method will need to take these individual differences into account when designing the methods.

CHAPTER THREE • METHODS

Chapter Three outlines the research methods of the study. As this will be an experimental design, this section includes the proposed research design, subject selection, stimuli, data collection techniques, data analysis techniques and statistical methods. The author proposes a new method to interpret the data and cites the methodological contributions this study will make to the field.

Research Methods

The primary focus of this study is to determine a subject's attention to various media (independent variables). This research will use the Electroencephalogram (EEG) to record and separate brain waves into their component waves. These component waves are the dependent variable used to measure attention and loss of attention. In addition to attention, the review of literature indicates that visual stimuli and, in particular luminance, are processed in two distinct areas of the brain. The ventral stream leads to the occipital lobes to process object identification and color (sometimes named the "what" stream) and the dorsal stream leads to the parietal lobes to process luminance leading to three dimensional rendering and spatial information (the "where" stream). Both of these areas of the brain will be sampled separately to see how the dorsal and ventral streams process media information differently.

Studying the brain creates some difficulty in measurement as the brain is encased in a thick, bony skull. The visual pathways involve pre-conscious firing of neuron groups in the occipital and posterior parietal areas. The nature of the brain, and of thinking in general, make self-reporting unreliable even if it were possible for a subject to really know accurately what was happening or what they were feeling as a result of brain function. Thinking about their thoughts would contaminate the study. Therefore it is necessary to look to other methods that record sub-conscious brain function.

There are several mechanical ways to measure brain activity, and for this study Electroencephalograms (EEG's) are used. Much of the brain has been mapped using Magnetic Resonance Imaging techniques and other brain imaging techniques to provide snapshots of the brain. However, this type of research is limited by access and expense of the measuring equipment, it requires highly trained professionals to interpret the results and requires the subject to lie inside a machine for an extended period of time with little access to a variety of media types. Mapping has been very useful to help researchers understand specific brain areas involved in processing specific types of information and because of this previous research we know where specific types of information are processed and where to "look" within the brain.

However, the recent work with Attention Deficit Disorder (ADD) and other studies cited in the review of literature, illustrates the ability of the EEG to accurately measure attention. Sterman, et. al. (1993) have also done extensive work with NASA using EEG feedback to develop adaptive task programs to assist pilots. And, as Bopar (1999) suggests, EEG's are related to both sensory and cognitive tasks, leading toward an "integrative neurophysiology" that explores synergies and synchronization within the brain. While other recording options capture a "snapshot" of the brain activity, EEG is useful for tracking changes in brain activity over a period of time, identifying patterns such as drowsiness or attention and for noting evoked responses to stimuli in fractions of a second.

Research Design

The primary focus of this study is to examine a subject's attention while reading using various media (independent variables). The research will use the Electroencephalogram (EEG) to record and separate brain waves into their component waves. These component waves are the dependent variable used to measure attention and loss of attention.

Edelman indicates that brain wave patterns are very individual and brain patterns vary even when subjects report the same outcome. This is due to the "re-entrant" function of the brain comparing the new information to past experiences, learning, emotions, etc. Edelman concludes, "it is clear that, among different individuals, each "representation", however similarly reported, was correlated with a widely variant reentrant pattern." (Edelman 2004, p. 109) With such individual patterns of brain waves, it would be difficult to establish a control group of subjects considered representative.

For this reason, a repeated measures design was used. Wimmer and Dominick (2000, p. 221) explain:

> *If information about the effects of multiple manipulations is desired, a repeated-measure design (several measurements of the same subject) is appropriate. In this design, instead of assigning different people to different manipulations, the researcher exposes the same subjects to multiple manipulations. The effects of the manipulations appear as variations within the person's performance rather than between groups. Since each subject in effect acts as his or her own control, the design is quite sensitive to detecting treatment differences.*

In this research, the subject was seated comfortably with her eyes closed and a baseline measure of the brain waves was recorded. Then the subject was asked to open her eyes and read the material located in front of her at eye level. After 20 seconds of recording, the subject closed her eyes to provide an end point and then was asked to slide the chair to the next station. The procedure was repeated for each treatment:

Resting I	Treatment	Resting II	Move
Eyes Closed	Eyes Open	Eyes Closed	to next
Alpha Pattern	Alpha Blocking	Alpha Pattern	treatment
establishes	anticipated	re-establishes	station.

The possible disadvantages of this method can be carryover effects from one treatment to the next. To guard against this, subjects were asked to close their eyes before and after each treatment and when they returned to a resting alpha baseline pattern, they proceeded to the next treatment. A second concern cited is that subjects will figure out the nature or purpose of the experiment and change their behavior. In this case, subjects knew in advance the nature of the experiment and while subjects can learn to alter brain waves, it takes many sessions of biofeedback (often 30 or more) to affect a change in brain patterns. For the average subject, the dependent variable of brain wave reactions will be automatic and beyond any control of the subject.

The data from each subject were recorded starting with the baseline reading with the eyes closed. An average value for five seconds of baseline reading just before the eyes were opened was determined. The subject opened her eyes and began reading. Five seconds of treatment EEG was averaged. In each case, any artifacts such as blinking or movement that appear in the EEG reading were removed before the average is calculated.

This research project tests three variables. First, subjects will be exposed to various media forms: print media viewed under daylight corrected incandescent lights, CRT computer monitor, and a LCD computer monitor. From these media, analysis was done to note differences between:

1) reflective light versus radiant light;

2) flickering radiant light sources versus non-flickering, reflective light sources;

3) flickering radiant light sources versus non-flickering, radiant light sources;

Reflective light media are defined as the print media treatments. Radiant light treatments include computer screens. Flickering light sources include fluorescent lighting, and CRT monitor.

Subjects

Subjects for this study were 15 Caucasian females ranging in age from 18 to 25. Initial subjects were invited to participate from college journalism classes and a snowball technique was used as subjects identified other subjects meeting the requirements and willing to be tested. Subjects were all right-handed, suffer from no mental disorders such as epilepsy or ADHD, report they did not currently use any mind-altering substances and had no history of head trauma or brain injury.

EEG research shows that the brain wave patterns are different for children than adults and that brain wave strength declines toward middle age. In general, brain waves stabilize after the age of 14 and begin to decline in middle age (Giannitrapani, 1988). Therefore, for this experiment, young adults ages 18 to 25 were selected. As part of the findings may address the impact of media use on higher education distance learning and classroom media use, college students are used in this study. This research study is comprised of 15 cases. As brain wave patterns can be affected by brain disorders including epilepsy, depression and ADHD, subjects with these patterns or taking medications to treat these conditions will not be eligible to participate as subjects. As gender, "handedness" (Giannitrapani, 1988) and race (Sandhu, 1996) can also make a difference in brain responses to light and reading, all subjects selected for this study were female, Caucasian and right handed.

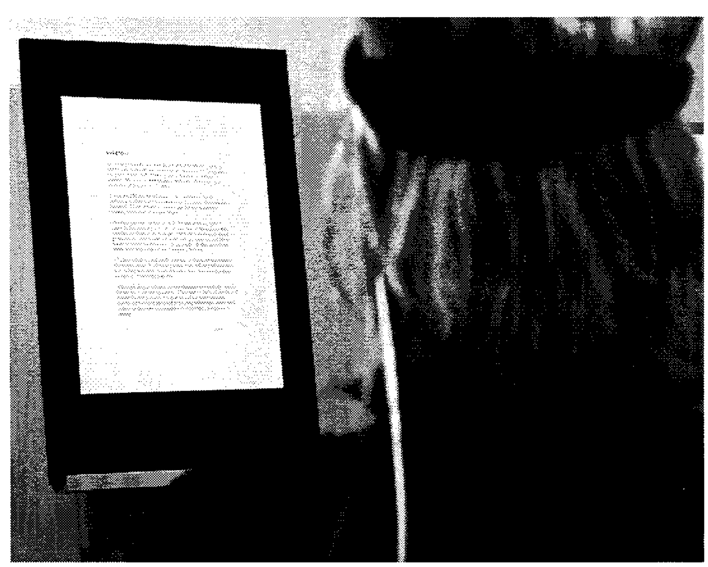
As the task involves reading, subjects were asked to wear appropriate corrective lenses if needed and as the test materials are written in English, this should be the subject's primary language. Subjects verified this information by filling out general demographic information. A brief learning style questionnaire was also administered to use in future analysis of the data collected. Subjects are compensated with a gift card.

A pre-test of two subjects was conducted to refine testing techniques and for sample data analysis.

Stimuli

All testing took place in a physiologic testing laboratory approximately 12 feet by 16 feet. All walls are painted white. The ceiling is a white drop-panel design with recessed fluorescent lights. Each set of fixtures contains three bulbs on separate switches. One bulb was replaced with full spectrum (known as sunshine or 5000K temperature) bulbs in the fixtures to guard against blue color contamination and the other two bulbs were traditional fluorescent to be used as a variable. The testing room is in a quiet area removed from hallways or distracting audio stimuli. The room has a separate heavy door to further guard against sound. If disruptive noise occurred the individual stimuli could be administered again, but this did not occur during testing.

Subjects sat in an adjustable height chair with a high back and armrests facing a blank white wall with white walls on both sides in peripheral vision. On the table in front of the subject was a 19" CRT computer monitor, a small stand to hold reflective materials and reading materials, a 17" flat panel monitor, a 19" Sony television and a light box consisting of a metal box with



fluorescent tubes covered with an translucent white plastic cover and masked to create an opening equal to the CRT monitors (only some of these treatments are used in this study.) Subjects rolled their chair approximately 18 inches from one treatment to the next and were allowed to get comfortable before closing their eyes to obtain the baseline reading. Subjects were allowed to adjust their position for comfortable reading distance but were otherwise instructed to remain still to minimize motion artifacts in the EEG.

For this experiment, paragraphs of copy were selected that were of factual, non-involving nature and all selected from the same book and author. Each paragraph had approximately 230 (plus or minus 5) words and was measured and corrected to have a similar Flesch reading difficulty score between grades 6 and 7 to provide similar reading material typical of average mass media. Based on previous readability studies for on-screen reading (Geske, 1996) 12 point type in a book style serif typeface was selected (Palatino). Line lengths of materials were adjusted to current reading standards of 2 to 2.5 alphabets per line. A sample reading material template was produced on transparent material and used as an overlay to assure each treatment met the same criteria for size regardless of screen format. Viewing sizes for paper and screens were all similar. All stimuli were presented directly in front of the subject at eye level.

The five media treatments were rotated using a Latin Square design to offset possible order effects. The three media treatments used in this study are:

1) The ambient or reflected light treatment uses high quality black laser printing on white paper for the reading sample. Each was mounted on a stiff black foam-core backing of similar size of the computer screen cases. This treatment will be tested using both fluorescent lighting and incandescent lighting. The incandescent lighted text is considered the standard and the variable is labeled PRINT.

2) The CRT screen uses a 17" Apple brand monitor set to the highest available resolution of 1280X 854 and set at the maximum level of brightness and 75 hz. Variable label is CRT.

3) The flat panel monitor uses a 17" Acer brand monitor set to the highest available resolution of 1280X 854 and set at the maximum level of brightness. Variable label is LCD.

Instructions were given to each subject from a script:

"The lab assistant will ask you to open and close your eyes between tests. When you open your eyes, read or study the object in front of you. When you close your eyes, try to relax as much as possible and do not open them until she tells you to. When we're running the tests, please don't move unless we tell you to. Please don't blink consciously, talk or swallow."

In each treatment, subjects closed their eyes in a relaxed mode for 20 seconds until an extended alpha pattern was noted. Subjects then opened their eyes and read or viewed the material in front of them for 20 seconds. Subject then moved to the next treatment and closed their eyes to return to an alpha state.

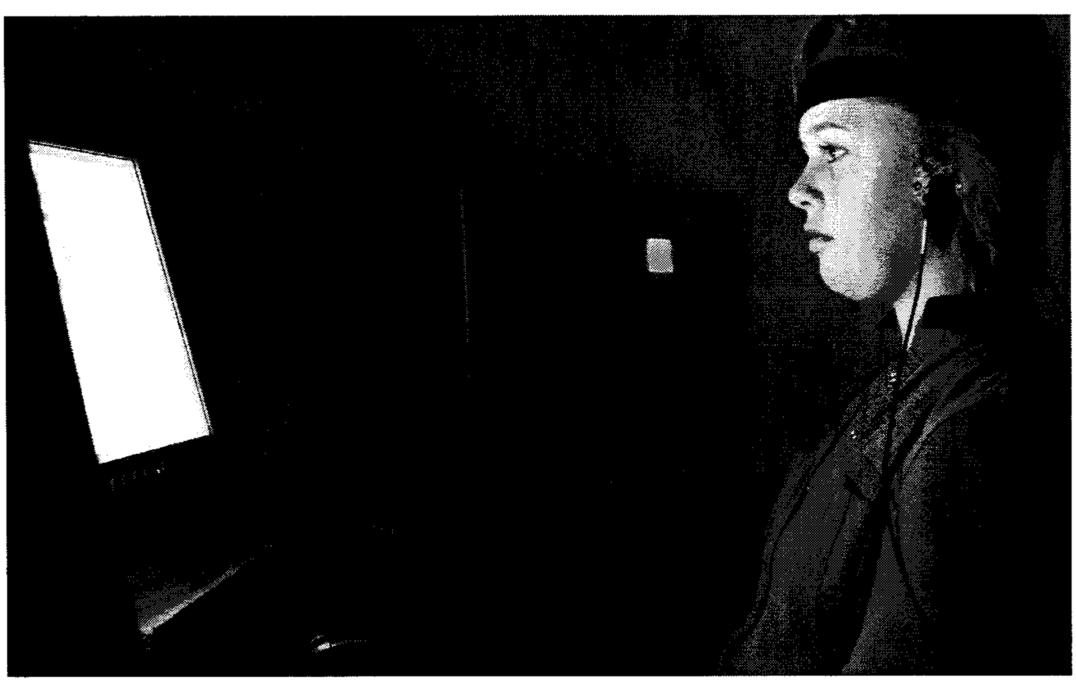
Measurement

The primary measurement is the EEG acquired with a BIOPAC MP30 Unit connected to a Macintosh G4 MiniMac computer. Data are acquired from the occipital lobes in each hemisphere and the posterior parietal lobes in each hemisphere. After the raw data are acquired and stored on the computer, it is filtered to individual waveforms and cleaned of any irregularities.

The subject is asked to assume a comfortable seated position in a chair providing good back support, arm rests and adjustable height for comfortable setting and minimal movement.

Disposable vinyl electrodes (Ag/AgCl) are positioned on the scalp of the subject using electrode gel to assure good contact and moving hair away from the scalp as much as possible. Slight pressure is applied to the electrodes for about a minute to assure a tight contact. One set of electrodes is placed on the left side of the head on the P3 region of the parietal lobe and the second set of electrodes on the O1 region of the occipital lobe.

Another set of electrodes is placed on the right side of the head on the P4 region of the parietal lobe and the second set of electrodes on the O2 region of the occipital lobe. A ground electrode for each side is connected on the ear lobe. (Electrode Placement follows the Modified Combinatorial Nomenclature, expanded '10-20' system as proposed by the American Clinical Neurophysiology Society). The subject's head is wrapped with a support wrap to secure electrode placement. The electrode cables are draped over the head so that they are not pulling on the electrodes.



The subject was asked to remain still as movements will affect the EEG recording. Data are digitally filtered to remove any unintended artifacts of movement. The room is kept quiet to help the subject mentally relax.

The equipment is calibrated for each subject as outlined in the equipment user's guide.

Post-acquisition analysis and transformations:

All analog signals are composed of signals of various frequencies. Like the color spectra where white light is made-up colors of different wavelengths, physiological signals are composed of specific signals with unique frequency signatures. Analog channels are used to acquire data with "continuous values." Nearly all physiological applications, where input devices are used, (for example, transducers and electrodes) produce a continuous stream of varying data.

Digital filtering:

With the help of digital filtering, it is possible to retain only the frequency components that are of interest and remove data (whether it is "noise" or merely physiological signals) that are not of interest.

This study uses an Infinite Impulse Response (IIR) filter. IIR is a type of digital signal filter which allows only the data within a specified range to pass through the filter. This Band Pass (low+high) filter is designed to allow a variable range of data to pass through the filter, when a low-frequency and high-frequency cut-offs are specified. For this study data were screened for frequencies from 1-30 to select the delta, theta, alpha and beta waves.

The BSL PRO software provided with the BIOPAC system performs a wide range of mathematical and computational transformations after an acquisition has been completed.

The following "Math Functions" from the AquireKnowledge software are used in the study (from the BioPac Instruction Manual):

Absolute Value:

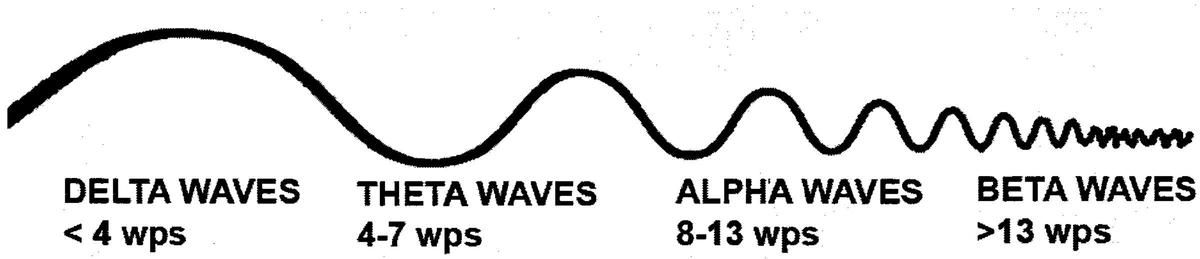
This math function computes the absolute value of the data. All negative data values are made positive, with no change in magnitude.

<u>*Math functions:*</u>

Computation of the frequency, mean, maximum and minimum amplitude of the individual wave. The Integral function will also be used as the primary means of measuring the power of individual wave segments as it combines the frequency and amplitude by calculating the total area under the curve.

Measuring the EEG Activity Levels

Applying these functions, information about each waveform can be obtained. The simplified diagram below shows that the brain waves are a continuum from the large, slow delta waves to faster (higher frequency) theta waves, to alpha waves. All three of these waveforms are fairly rhythmic. When a person attends to a stimuli the rhythm breaks up as more neuron groups are stimulated and smaller "choppier" beta waves are produced, the beta waves.



As previously described, a predominance of alpha waves found in the areas of the occipital lobes and parietal lobes characterizes relaxation or meditation. These are relatively large, slow wave patterns and are used as the standard eyes-closed measurement. Attentive arousal is associated with desynchronized EEG activity of weak amplitude in the beta range. Drowsiness or loss of consciousness is associated with an increase in the slower and higher amplitude theta and delta waves.

It is to be expected that when subjects move from a relaxed, eyes-closed state (the control state for this experiment) to an eyes open state:

1) a decrease in alpha wave activity and therefore a decrease in total area under the curve;

2) a decrease in total area under the beta curve since beta activity is inversely proportionate to attention (a smaller, tighter beta indicates more attention);

3) should there be a shift toward more theta and delta activity, it indicates the subject is getting bored or sleepy.

Subjects were allowed to read for twenty seconds and the first five seconds after any spike or artifact from the motion of the eye opening were averaged and used as the measure.

Put into numerical form, a sample subject report would look like this:

Subject 3							
CRT	Alpha O	Beta O	Theta O	CRT	Alpha P	Beta P	Theta P
EC	21.27	25.79	30.46	EC	14.87	13.08	12.14
Read	31.87	52.01	19.66	Read	10.14	11.08	5.90
	-10.60	-26.22	10.80		4.73	2.00	6.24
% Change	-49.84	-101.67	35.46	% Change	31.81	15.29	51.40
PRINT	Alpha O	Beta O	Theta O	PRINT	Alpha P	Beta P	Theta P
EC	40.04	26.05	22.30	EC	19.71	20.83	10.04
Read	9.48	19.10	8.97	Read	4.5	7.34	6.44
	30.56	6.95	13.33		15.21	13.49	3.6
% Change	76.32	26.68	59.78	% Change	77.17	64.76	35.86

Each treatment starts with the eyes closed (EC) as the baseline to measure from. The two treatments shown above are reading from a CRT screen and print. The alpha, beta and theta waves are reported for both the occipital lobes (O, the left portion of the chart) and parietal lobes (P, the right portion of the chart).

This example shows that for the print treatment, the alpha level (alpha blocking) did occur with the alpha level decreasing from 40.04 to 9.48 for a 76% change. The raw difference is computed and more importantly, as each baseline can vary greatly, the percentage of change from the baseline is computed. In this same example, one can note that in the CRT stimuli the alpha blocking did not occur and in fact the alpha (and beta) increased, indicating a move away from attention.

Therefore, since we know the smaller, more intense the wave measurement (smaller numbers) indicates more attention, and larger wave forms (larger numbers) indicate a move away from attention, one can calculate the difference between the baseline and the treatment to find:

- all positive numbers will indicate an increase in attention;
- all negative numbers will indicate a decrease in attention;
- the larger the difference in a positive direction, and therefore a larger percentage change, the greater the attention indicated by that treatments;
- the larger the difference in a negative direction, and therefore a larger percentage change the greater the loss of attention indicated by the treatment.

Since the baseline numbers vary considerably within subjects and between subjects, the percentage change from the baseline is the most accurate measure and is used for the test statistics.

Interpretation of Results and Statistical Methods

Results are reviewed on a case-by-case basis as is traditional in many EEG studies to see if the data indicate a directional movement toward or away from attention. While many studies stop at this interpretation, this study, with the newly devised numerical reporting, also tested for statistically significant differences of attention between media. To see if there are statistical differences between the treatments, a paired samples t-test will be used if the data is normally distributed or the non-parametric equivalent, the Wilcoxon Signed Rank Test was used.

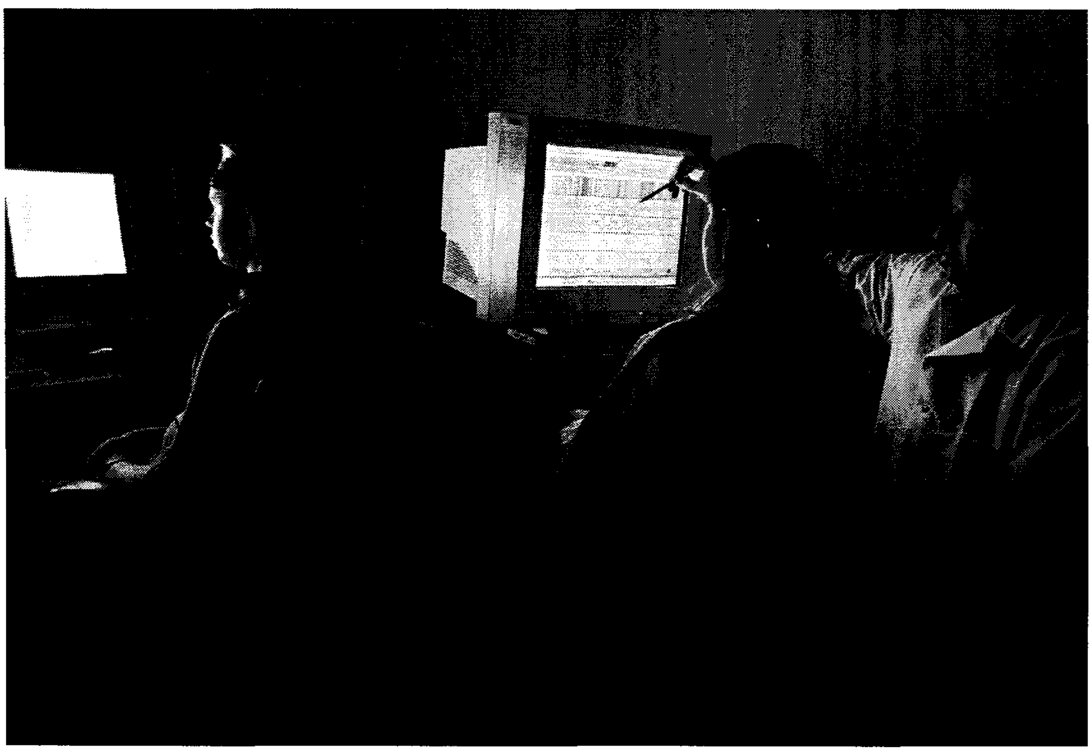
Conclusions

While not the focus of this work, the methods and interpretation outlined provides a new way to look at the brain wave patterns. In addition, this author has seen no studies that specifically segregate the occipital and parietal lobes to test reactions from the ventral (what) and dorsal (where) streams of visual information. In addition to the practical applications of media use, these two advancements should provide a significant contribution to future research in this field.

CHAPTER FOUR • FINDINGS

The findings section explores the data collected from 15 female Caucasian subjects to determine if media choice influences attention to reading. The findings are organized by first presenting general guidelines for measuring the brain waves and how the data are recorded.

Next each research question and the related hypotheses are examined individually with related data tables and statistical analysis and each hypothesis is accepted or rejected.



Analysis of Brain Patterns

As previously described, a predominance of alpha waves found in the areas of the occipital lobes and parietal lobes characterizes relaxation or meditation. These are relatively large, slow wave patterns. Attentive arousal is associated with desynchronized EEG activity of weak amplitude in the beta range. This indicates that more neuron groups are processing information, so a greater movement away from the baseline of eyes closed will indicate more attention. Drowsiness or loss of consciousness is associated with an increase in the slower theta and delta waves.

It is to be expected that when subjects move from a relaxed, eyes-closed state (the control state for this experiment) to an eyes open state viewing stimuli, that there will be:

1) a decrease in alpha wave activity and therefore decrease in total area under the curve;

2) since beta activity is inversely proportionate to attention, there should also be a decrease in total area under the beta curve (a smaller, tighter beta indicates more attention) and a greater movement away from the baseline;

3) should there be a shift toward more slow alpha, theta and delta activity, it indicates the subject is getting bored or sleepy. This would be indicated by a negative number.

Since eyes closed is the control and the treatment is now measured as an interval from the control, simple subtraction gives one a final measure -- the amount of change from the control to treatment in Charts 2 and 3. This step removes the differences in baseline between subjects and between treatments. This provides ratio data which can be tested statistically for differences.

Therefore, the way the charts are arranged after calculating the differences from the baseline to the treatment:

- all positive numbers will indicate an increase in attention as the waves became smaller in relation to the baseline reading and resulting in a higher percentage change.
- a larger positive number indicates an greater increase in attention as the wave forms become smaller and lower amplitude and move "further" from the baseline reading for each subject.
- all negative numbers indicate a decrease in attention meaning that the waves became larger when compared to the baseline.

Pretests

To confirm data analysis procedures, data were collected from three pre-test subjects. This allowed preliminary data collection techniques to be refined before the subjects were tested. Pre-test subjects were tested using print materials and television rather than computer screens.

This sample chart shows the original data collected for each section of the brain, and each wave form. The area measurement provides measurement of both frequency and amplitude of the wave. Note: Top half of chart is data for reading as measured in the parietal and occipital lobes of the brain (primary visual processing areas). Below the gray line is data for television viewing. EC= eyes closed for the baseline before exposure to stimuli.

Table 4-1. Prestest Subject Data Sample

READ										
Parietal						Occipital				
Alpha	max	min	mean	area		Alpha	max	min	mean	area
EC	2.38	-2.45	0.00	24.06		EC	6.52	-6.83	0.00	44.67
Read	2.76	-2.73	0.00	23.04		Read	5.09	-4.99	0.00	41.31
Beta	max	min	mean	area		Beta	max	min	mean	area
EC	4.81	-5.90	0.01	33.66		EC	9.99	-9.84	0.00	81.51
Read	4.18	-3.87	0.01	32.72		Read	10.29	-10.96	0.00	82.90
Theta	max	min	mean	area		Theta	max	min	mean	area
EC	3.03	-2.71	0.02	22.86		EC	2.65	-2.63	0.00	27.11
Read	3.05	-3.14	0.02	21.64		Read	2.91	-2.74	0.00	24.97
Delta	max	min	mean	area		Delta	max	min	mean	area
EC	-3.45	-12.32	-6.82	72.95		EC	9.06	-2.53	0.53	122.28
Read	-3.94	-14.00	-8.06	45.16		Read	3.84	-3.35	0.21	37.08
TV										
Alpha	max	min	mean	area		Alpha	max	min	mean	area
EC	4.41	-4.13	0.00	41.75		EC	5.31	-5.45	0.00	51.37
TV	2.37	-2.39	0.00	22.22		TV	7.17	-6.80	0.00	47.59
Beta	max	min	mean	area		Beta	max	min	mean	area
EC	9.39	-10.15	0.01	61.80		EC	9.24	-9.17	0.00	59.05
TV	5.01	-4.42	0.01	49.68		TV	11.82	-11.11	0.00	229.04
Theta	max	min	mean	area		Theta	max	min	mean	area
EC	7.25	-7.44	0.01	29.49		EC	3.07	-3.34	0.00	44.77
TV	2.86	-3.66	0.02	28.47		TV	2.79	-2.78	0.00	30.16
Delta	max	min	mean	area		Delta	max	min	mean	area
EC	7.56	-19.86	-4.87	125.78		EC	7.97	-4.82	0.34	48.20
TV	-1.13	-23.21	-8.89	246.64		TV	2.25	-18.31	-3.11	225.16

Condensed Data

The data from the above chart were condensed to simply the area under the curve for the baseline (EC) and the treatment and subtracted. A percentage is calculated and all positive numbers indicate a move toward more attention and all negative numbers indicate a move away from attention.

Table 4-2. Prestest Subject One Data Sample

PARIETAL					OCCIPITAL				
	Alpha	Beta	Delta	Theta		Alpha	Beta	Delta	Theta
EC	24.06	33.66	72.95	22.86	EC	44.67	81.51	122.28	27.11
Reading	23.04	32.72	45.16	21.64	Reading	41.31	82.90	37.08	24.97
	1.02	0.94	27.79	1.22		3.36	-1.39	85.20	2.14
% Change	4.24	2.79	38.09	5.34	% Change	7.52	-1.71	69.68	7.89
	Alpha	Beta	Delta	Theta		Alpha	Beta	Delta	Theta
EC	41.75	61.80	125.00	29.49	EC	51.37	59.00	48.00	44.77
TV	22.22	49.68	146.00	28.47	TV	47.59	129.00	125.00	30.16
	19.53	12.12	-20.00	1.02		3.79	-69.00	-76.00	14.60
% Change	46.78	19.61	-16.00	3.46	% Change	7.38	-116.95	-158.33	32.61

Second Sample Pretest Subject "AP"

A second subject example is included to show the wide variation that can occur between subjects and even different patterns between parts of the brain for different subjects (eg. The alpha patterns are almost reverses between the two subjects for occipital and parietal lobes and the baseline varies widely).

Table 4-3. Prestest Subject Two Data Sample

PARIETAL						OCCIPITAL				
	Alpha	Beta	Delta	Theta			Alpha	Beta	Delta	Theta
EC	40.70	34.80	29.80	28.70		EC	22.00	18.40	42.40	22.20
Reading	27.50	32.64	23.70	23.00		Reading	14.60	17.70	39.00	21.80
	13.20	2.24	6.10	5.70			7.40	0.70	3.40	0.40
% Change	32.43	6.44	20.47	19.86		% Change	33.64	3.80	8.02	1.80
	Alpha	Beta	Delta	Theta			Alpha	Beta	Delta	Theta
EC	33.50	40.60	27.40	23.00		EC	21.80	21.20	27.60	16.50
TV	20.40	24.90	31.60	30.90		TV	16.80	18.40	29.70	20.10
	13.10	15.70	-4.20	-7.90			3.79	2.80	-2.10	-3.60
% Change	39.10	38.67	-15.33	-34.35		% Change	17.39	13.21	-7.61	-21.82

For two subjects shown above, both exhibited alpha blocking and general levels of attention for all wave forms for reading (there is a slight indication of loss of beta activity for subject one in the occipital lobes, but as reading and language is handled primarily in the parietal lobes, this is not a big factor.) Both subjects show a move toward inattention or drowsiness in the TV sampling with increasing delta and theta activity indicated by the negative numbers. Subject one shows a strong negative reaction in beta to TV that can't be explained by an artifact such as movement, as it does not show up in the other lobes.

This method greatly simplifies interpretation of attention patterns for EEG measurements. It also simplifies interpreting data that can vary widely by subject and within subject. However, at this point, the author knows of no studies that connect the percentages of increase to quantifiable increases in attention. At this point all one can say is that attention increased and perhaps that attention increased MORE with one treatment over the other. However there is no real way to quantify that subjects showed X times more attention for one treatment over the other.

Charts for each subject are included in the Appendix labeled Charts and the data analysis following uses summary charts and provides the statistical analysis.

Statistical Analysis of Data

The percentage change score shows the amount of change from the baseline data and in effect eliminates the variation in baselines. This number was entered into SPSS for statistical analysis when appropriate. Since this research uses a small sample and is exploratory in nature, a significance level of .10 was chosen for comparison of media. However for tests of normality and statistical procedures that would affect the underlying assumptions of the statistical tests, such as a t-test, a more standard p=.05 standard is used. At this stage of exploration, the researcher is looking for broad differences in media and there is little negative impact should there be findings reported that happened by chance.

Since a small sample is tested, the first step was to check the data for normal distribution using the Shapiro–Wilk test for normality.

Table 4-4. Shapiro-Wilk Test for Normality p=.05

Variable	Statistic	df	Sig.	Distribution
PrintAlphaOcc	.884	15	.054	
PrintAlphaPar	.941	15	.392	
LCDAlphaOcc	.834	15	.011	Not Normally Distributed
LCDAlphaPar	.952	15	.563	
CRTAlphaOcc	.887	15	.061	
CRTAlphaPar	.904	15	.111	
PrintBetaOcc	.768	15	.001	Not Normally Distributed
PrintBetaPar	.921	15	.200	
LCDBetaOcc	.898	15	.087	
LCDBetaPar	.894	15	.078	
CRTBetaOcc	.926	15	.238	
CRTBetaPar	.834	15	.010	Not Normally Distributed
PrintThetaOcc	.876	15	.041	Not Normally Distributed
PrintThetaPar	.904	15	.110	
LCDTheta Occ	.892	15	.072	
LCDTheta Par	.753	15	.001	Not Normally Distributed
CRTThetaOcc	.849	15	.017	Not Normally Distributed
CRTThetaPar	.929	15	.268	

As Table 4-4 indicates, 6 of the 24 variables included in this study do not have a normal distribution of data. For this reason, the non-parametric Wilcoxon Signed Rank Test will be used to provide the test statistic, to compare treatment means, rather than using a t-test, which assumes normal distribution of data.

Research Questions

Since one of the major indications of increased attention is the Alpha blocking this will be explored in each of the first research questions, first for the occipital lobes and then the parietal lobes for each medium examined. For example, if CRT screens do cause similar reactions as TV picture tubes, there should be limited or no alpha blocking for the CRT screens or less alpha blocking than print materials.

For ease of reading and understanding, each research question will be stated and the related hypotheses examined before moving on to the next research question.

Research Question One:

Does the medium affect the visual processing areas of the brain (occipital and parietal lobes) differently?

H1) Subjects will show greater occipital activity and more "alpha blocking" when reading than when in a resting state as indicated by a reduction in alpha wave activity.

Table 4-5. Alpha Blocking in Occipital Lobes

SUBJECT	CRT	PRINT	MEDIUM WITH GREATER BLOCKING
1	No	Yes	Print shows greater block
2	Yes	No	CRT
3	No	Yes	Print
4	Yes	Yes	CRT
5	Yes	Yes	Print
6	Yes	Yes	Print
7	Yes	Yes	Print.
8	Yes	Yes	Print
9	No	Yes	Print
10	Yes	Yes	Print
11	Yes	Yes	Print
12	Yes	Yes	CRT
13	Yes	No	CRT
14	Yes	Yes	Print
15	Yes	Yes	Print

Twelve of the 15 subjects showed alpha blocking in the occipital lobes when reading on a CRT screen. Thirteen of the 15 subjects showed alpha blocking in the occipital lobes when reading print materials. Eleven of the 15 subjects (73%) showed greater alpha blocking, indicating more attention, for the print materials. Hypothesis accepted.

H2) Subjects will show greater <u>parietal</u> activity and more "alpha blocking" when reading than when in a resting state as indicated by a reduction in alpha wave activity.

Table 4-6. Alpha Blocking in Parietal Lobes

SUBJECT	CRT	PRINT	MEDIUM WITH GREATER BLOCKING
1	Yes	Yes	Print shows greater block
2	Yes	Yes	Print
3	Yes	Yes	Print
4	No	Yes	CRT
5	Yes	No	CRT (CRT had almost no block; less than 2% change)
6	Yes	Yes	Print
7	Yes	Yes	CRT (Very close scores)
8	Yes	Yes	CRT (Print had almost no block)
9	No	No	Neither
10	No	Yes	Print
11	No	Yes	Print
12	Yes	Yes	CRT •
13	Yes	Yes	Print
14	Yes	Yes	Print
15	Yes	Yes	Print

Eleven of the 15 subjects (73%) showed alpha blocking in the parietal lobes when reading on a CRT screen. Thirteen of the 15 subjects (87%) showed alpha blocking in the parietal lobes when reading print materials. One subject had no alpha blocking for either medium and of the remaining 14 subjects, nine (64%) showed greater alpha blocking, indicating more attention, for the print materials. Hypothesis accepted.

When a subject goes from eyes closed (high alpha state) to eyes open, one would expect alpha blocking to occur in every case. This occurred for print materials except for one subject where no alpha blocking occurred for either medium and one that did not for print only. One would expect the same to happen for the CRT screen but 27% of the subjects did not exhibit alpha blocking in the parietal lobes.

The averages do indicate overall alpha blocking for both occipital and parietal lobes. In both lobes, there is more alpha blocking for print materials than CRT screen. In general, this would indicate more attention, on average, for the print materials.

As expected, alpha blocking was exhibited in the majority of the cells (15 subjects x 2 treatments x 2 brain locations= 60 cells). However, as the alpha blocking is well documented in nearly all patients, the fact that nine subjects, more than half the total subjects, did not exhibit the alpha block in at least one cell is quite interesting.

Table 4-7. Observed Lack of Alpha Blocking

SUBJECT	OBSERVED ALPHA
1	No alpha block in CRT Occipital
2	No alpha block in Print Occipital
3	No alpha block in CRT Occipital
4	No alpha block in CRT Parietal
5	No alpha block in Print Parietal
9	No alpha block in CRT Occipital
9	No alpha block in CRT Parietal
9	No alpha block in Print Occipital
10	No alpha block in CRT Parietal
11	No alpha block in CRT Parietal
13	No alpha block in Print Occipital

This indicates that the entire "visual processing areas" of the occipital and parietal lobes should not be considered one unit. There are obvious individual differences that occur in processing in both print and CRT. Six of the nine individuals show an increase of alpha for CRT screens (rather than the anticipated alpha blocking). This would support Krugman's study on television which showed an increase in Alpha activity and loss of attention for CRT-type screens.

The original hypothesis stated "The first two hypotheses are almost a given…" However, as over half the subjects did not exhibit alpha blocking in all situations (especially CRT screens), it raises interesting questions as alpha blocking would be expected for all subjects unless, as Mulholland indicates they are not moving their eyes or focusing the eye.

Overall, H1 and H2 are accepted. Thirteen of the 15 subjects showed alpha blocking for print materials in the parietal lobes and 13 of the 15 (86%) for the occipital lobes. Only 11 of 15 (73%) show alpha blocking in the parietal lobes for CRT and 13 of the 15 (86%) for Print.

Since the work with television screens shows a lessening of attention and CRT screens are similar in construction, it leads to the hypotheses:

H3) Subjects will show brain patterns of greater attention as indicated by a greater shift in beta activity in the occipital lobes when reading using print media and lower attention when reading using CRT computer screen.

Recalling that the way the data are recorded, a larger positive number indicates more attention indicated by a smaller tighter beta wave in relation to the eyes- closed baseline. A negative number indicates a larger, less defined beta wave activity compared to the eyes-closed baseline.

Table 4-8. Comparison of beta wave activity in occipital lobes

CRT vs. Print (Incandescent Lights)

crtbetao	printbetao	
5.55	-98.04	
45.35	41.44	
-101.67	26.68	Less beta attention for CRT
29.93	56.95	
35.67	54.65	Less beta attention for CRT
25.87	23.80	
55.48	34.66	
64.12	53.72	
-13.41	17.30	Less beta attention for CRT
-33.41	8.32	Less beta attention for CRT
23.62	39.78	Less beta attention for CRT
-6.50	37.71	Less beta attention for CRT
2.01	34.56	Less beta attention for CRT
83.77	74.14	
45.86	-2.80	

For the occipital lobes, seven subjects showed less attention as measured by beta activity for the CRT screen treatment and eight subjects showed less attention as measured by beta activity for the print treatment.

Wilcoxon Signed Rank Test for Significance

		N	Mean Rank	Sum of Ranks	
CRTBetaOcc - PrintBetaOcc	Negative Ranks	8	9.50	76.00	CRTBetaOccr< PrintBetaOcc
	Positive Ranks	7	6.29	44.00	CRTBetaOcc > PrintBetaOcc
	Ties	0			PrintBetaOcc = CRTBetaOcc
	Total	15			

Test Statistics • Wilcoxon Signed Ranks Test

	CRTBetaOcc - PrintBetaOcc	
Z	-.909	Based on positive ranks
Asymp. Sig. (2-tailed)	.363	

Hypothesis Three is rejected. The data show no significant difference in beta activity in the occipital lobes between CRT and Print.

H4) Subjects will show brain patterns of greater attention in the parietal lobes as indicated by a greater shift in beta activity when reading using print media and lower attention when reading using CRT computer screen.

Recalling that the way the data are recorded, a larger positive number indicates more attention indicated by a smaller tighter beta wave in relation to the eyes-closed baseline. A negative number indicates a larger, less defined beta wave activity compared to the eyes-closed baseline.

Table 4-9. Comparison of beta wave activity in Parietal Lobes • CRT vs. Print

crtbetap	printbetap	
-14.87	58.22	Less beta attention for CRT
62.74	75.07	Less beta attention for CRT
15.29	75.37	Less beta attention for CRT
35.34	12.69	
-144.15	42.00	Less beta attention for CRT
33.52	67.01	Less beta attention for CRT
48.03	12.55	
64.12	34.02	
-22.00	25.18	Less beta attention for CRT
-60.56	-5.27	Less beta attention for CRT
38.18	35.03	
20.56	57.75	Less beta attention for CRT
-18.34	55.84	Less beta attention for CRT
58.14	68.96	Less beta attention for CRT
32.47	-5.19	

For the parietal lobes, 10 subjects (66%) showed less attention as measured by beta activity for the CRT screen treatment and five subjects showed less attention as measured by beta activity for the print treatment.

Table 4-10 Wilcoxon Signed Rank Test for Significance **p=.10**

		N	Mean Rank	Sum of Ranks	
CRTBetaPar - PrintBetaPar	Negative Ranks	10	9.40	94.00	CRTBetaPar < PrintBetaPar
	Positive Ranks	5	5.20	26.00	CRTBetaPar > PrintBetaPar
	Ties	0			PrintBetaPar = CRTBetaPar
	Total	15			

Test Statistics • Wilcoxon Signed Ranks Test

	CRTBetaPar - PrintBetaPar	
Z	-1.931	Based on positive ranks
Asymp. Sig. (2-tailed)	.053	

The data indicate a significant difference (p=.10) with more attention to print materials as indicated by beta activity in the parietal lobes.

Research Question Two:

Do mechanical artifacts such as flicker on a CRT screen create different brain patterns in these visual processing areas when reading?

To measure this, one can compare similar screens such as CRT screens that use an "electron gun" mechanism with an inherent flicker as the gun passes along the screen path, and an LCD screen in which pixels are simply "on" or "off" without the flicker pattern. If flicker does cause attention problems, it could show up with less attention to the CRT screen than the LCD screen.

Once again, the first way to measure attention difference is to look to the alpha block.

H5) Subjects will show greater occipital activity and more "alpha blocking" when reading from a LCD than when reading from a CRT screen.

Table 4-11. Alpha Blocking in Occipital Lobes

SUBJECT	CRT	LCD	MEDIUM WITH GREATER BLOCKING
1	No	Yes	LCD shows greater block
2	Yes	Yes	CRT
3	No	Yes	LCD
4	Yes	Yes	CRT
5	Yes	Yes	LCD
6	Yes	Yes	LCD
7	Yes	Yes	LCD
8	Yes	Yes	LCD
9	No	Yes	LCD
10	Yes	Yes	LCD
11	Yes	Yes	CRT
12	Yes	Yes	CRT
13	Yes	Yes	CRT
14	Yes	Yes	CRT
15	Yes	No	CRT

For the occipital lobes, 12 of 15 subjects (80%) exhibited alpha blocking for the CRT screens and all but one (93%) for LCD screens. With eight subjects showing greater alpha blocking for the LCD screen and seven subjects sowing greater alpha blocking for the CRT screen, this hypothesis is not accepted.

H6) Subjects will show greater parietal activity and more "alpha blocking" when reading from a LCD than when reading from a CRT screen.

Table 4-12. Alpha Blocking in Parietal Lobes

SUBJECT	CRT	LCD	MEDIUM WITH GREATER BLOCKING
1	Yes	Yes	CRT shows greater block
2	Yes	Yes	CRT
3	Yes	Yes	LCD
4	No	Yes	LCD
5	Yes	Yes	LCD (CRT had almost no block)
6	Yes	Yes	LCD
7	Yes	Yes	CRT
8	Yes	Yes	LCD
9	No	Yes	LCD
10	No	Yes	LCD
11	No	No	Neither exhibited alpha block
12	Yes	Yes	LCD
13	Yes	Yes	CRT
14	Yes	Yes	CRT but almost a tie
15	Yes	Yes	LCD

For the parietal lobes, 11 of 15 subjects (73%) exhibited alpha blocking for the CRT screens and all but one (93%) for LCD screens and that individual did not exhibit alpha blocking for either medium. Nine subjects exhibited more alpha blocking for the LCD, while five exhibited more for the CRT and one subject had no alpha block for either treatment. Based on this data, hypothesis seven is cautiously accepted.

H7) Subjects will show brain patterns of greater attention as indicated by a greater shift in beta activity in the occipital lobes when reading from a LCD screen and lower attention when reading using CRT computer screen.

Table 4-13. Comparison of beta wave activity in occipital lobes • CRT vs. LCD

crtbetao	lcdbetao	
5.55	-42.81	
45.35	31.02	
-101.67	67.88	Less beta attention for CRT
29.93	59.99	Less beta attention for CRT
35.67	63.11	Less beta attention for CRT
25.87	18.89	
55.48	44.95	
64.12	40.96	
-13.41	-20.19	Both increased beta...indicates lack of attention. CRT smaller
-33.41	40.57	Less beta attention for CRT
23.62	20.18	
-6.50	67.10	Less beta attention for CRT
2.01	22.08	Less beta attention for CRT
83.77	54.27	
45.86	-18.63	

The preliminary data suggest little difference in the overall beta patterns in the occipital lobes. Seven subjects show less attention to the CRT screen and eight subjects show less attention to the LCD. The significance test following confirms this conclusion, show no significant differences in the beta in the occipital lobes and this hypothesis is not accepted.

Table 4-14. Wilcoxon Signed Rank Test for Significance p=.10

Variable		N	Mean Rank	Sum of Ranks	
CRTBetaOcc - LCDBetaOcc	Negative Ranks	6	11.00	66.00	CRTBetaOcc< LCDBetaOcc
	Positive Ranks	9	6.00	54.00	CRTBetaOcc > LCDBetaOcc
	Ties	0			LCDBetaOcc = CRTBetaOcc
	Total	15			

Test Statistic • Wilcoxon Signed Ranks Test

	CRTBetaOcc - PrintBetaOcc	
Z	-.341	Based on positive ranks
Asymp. Sig. (2-tailed)	.733	

H8) Subjects will show brain patterns of greater attention in the parietal lobes as indicated by a greater shift in beta activity when reading from a LCD screen and lower attention when reading using CRT computer screen.

Table 4-15. Comparison of beta wave activity in Parietal Lobes CRT vs. LCD

crtbetap	lcdbetap	
-14.87	49.04	Less beta attention for CRT
62.74	75.45	Less beta attention for CRT
15.29	65.70	Less beta attention for CRT
35.34	1.58	
-144.15	21.17	Less beta attention for CRT
33.52	74.95	Less beta attention for CRT
48.03	17.81	
64.12	23.88	
-22.00	18.71	Less beta attention for CRT
-60.56	18.49	Less beta attention for CRT
38.18	-0.35	
20.56	68.43	Less beta attention for CRT
-18.34	36.25	Less beta attention for CRT
58.14	59.43	Less beta attention for CRT
32.47	16.01	

The preliminary data above suggest a difference in the overall beta patterns in the parietal lobes. Ten subjects show less attention to the CRT screen and five subjects show less attention to the LCD. The significance test confirms this conclusion, showing significant differences (p=.10) in the beta in the occipital lobes. Hypothesis accepted.

Table 4-16. Wilcoxon Signed Rank Test for Significance p=.10

Variable		N	Mean Rank	Sum of Ranks	
CRTBetaPar - LCDBetaPar	Negative Ranks	10	9.50	95.00	CRTBetaPar < LCDBetaPar
	Positive Ranks	5	5.00	25.00	CRTBetaPar > LCDBetaPar
	Ties	0			LCDBetaPar = CRTBetaPar
	Total	15			

Test Statistics • Wilcoxon Signed Ranks Test

	CRTBetaPar - PrintBetaPar	
Z	-1.988	Based on positive ranks
Asymp. Sig. (2-tailed)	.047	

Research question three:

If there is a difference, is it due to the flicker effect or radiant lighting versus ambient lighting?

To test this question, the radiant light, non-flicker LCD screen can be tested against the ambient light print treatment which also lacks any flicker effect as it has incandescent lighting.

Once again, the first measure attention difference is to look to the Alpha block.

H9) Subjects will show greater occipital activity and more "alpha blocking" when reading from a print source than when reading from a LCD screen.

Table 4-17. Alpha Blocking in Occipital Lobes

SUBJECT	PRINT	LCD	MEDIUM WITH GREATER BLOCKING
1	Yes	No	Print shows greater block
2	No	Yes	LCD
3	Yes	Yes	Print
4	Yes	Yes	Print
5	Yes	Yes	LCD
6	Yes	Yes	LCD
7	Yes	Yes	LCD
8	Yes	Yes	LCD
9	Yes	Yes	Print
10	Yes	Yes	LCD
11	Yes	Yes	Print
12	Yes	Yes	LCD
13	No	Yes	LCD
14	Yes	Yes	Print
15	No	No	Neither showed alpha blocking

For the occipital lobes, 12 of 15 subjects (80%) exhibited alpha blocking for the Print and all but one (93%) for LCD screens. With eight subjects showing greater alpha blocking for the LCD screen and six subjects sowing greater alpha blocking for print and one subject showing no alpha block for either, this hypothesis is not accepted.

H10) Subjects will show greater <u>parietal</u> activity and more "alpha blocking" when reading from print than when reading from a LCD screen.

Table 4-18. Alpha Blocking in Parietal Lobes

SUBJECT	Print	LCD	MEDIUM WITH GREATER BLOCKING
1	Yes	Yes	LCD shows greater block
2	Yes	Yes	Print
3	Yes	Yes	LCD
4	Yes	Yes	Print
5	No	Yes	LCD
6	Yes	Yes	Print
7	Yes	Yes	Print
8	Yes	Yes	LCD
9	No	Yes	LCD
10	Yes	Yes	Print
11	Yes	No	Print
12	Yes	Yes	LCD
13	Yes	Yes	Print
14	Yes	Yes	Print
15	Yes	Yes	LCD

For the parietal lobes, 13 of 15 subjects (87%) exhibited alpha blocking for the print and all but one (93%) for LCD screens. Seven subjects exhibited more alpha blocking for the LCD, while eight exhibited more for print. The hypothesis is rejected. There appears to be little difference in alpha blocking in the parietal lobes when reading from print or LCD screen.

H11) Subjects will show brain patterns of greater attention as indicated by a greater shift in beta activity in the occipital lobes when reading in print and lower attention when reading using an LCD computer screen.

Table 4-19. Comparison of beta wave activity in Occipital Lobes PRINT vs. LCD

printbetao	lcdbetao	
-98.04	-42.81	
41.44	31.02	Less beta attention for LCD
26.68	67.88	Less beta attention for LCD
56.95	59.99	
54.65	63.11	
23.80	18.89	Less beta attention for LCD
34.66	44.95	
53.72	40.96	Less beta attention for LCD
17.30	-20.19	Less beta attention for LCD
8.32	40.57	
39.78	20.18	Less beta attention for LCD
37.71	67.10	
34.56	22.08	Less beta attention for LCD
74.14	54.27	Less beta attention for LCD
-2.80	-18.63	Less beta attention for LCD

The preliminary data suggest some difference in the overall beta patterns in the occipital lobes. Six subjects show less attention to print and nine subjects show less attention to the LCD. However, the significance test following shows no significant differences in the beta in the occipital lobes (and in fact shows they are equivalent) and this hypothesis is not accepted.

Table 4-20. Wilcoxon Signed Rank Test for Significance **p=.10**

Variable		N	Mean Rank	Sum of Ranks	
PrintBetaOcc - LCDBetaOcc	Negative Ranks	8	7.50	60.00	LCDBetaOcc< PrintBetaOcc
	Positive Ranks	7	8.570	60.00	LCDBetaOcc > PrintBetaOcc
	Ties	0			LCDBetaOcc = PrintBetaOcc
	Total	15			

Test Statistics • Wilcoxon Signed Ranks Test

	LCDBetaOcc - PrintBetaOcc	
Z	.000[a]	Sum of negative ranks = sum of positive ranks
Asymp. Sig. (2-tailed)	1.000	

H12) Subjects will show brain patterns of greater attention in the parietal lobes as indicated by a greater shift in beta activity when reading from print and lower attention when reading using LCD computer screen.

Table 4-21. Comparison of beta wave activity in Parietal Lobes PRINT vs. LCD

printbetap	lcdbetap	
58.22	49.04	Less beta attention for LCD
75.07	75.45	(Virtually a tie)
75.37	65.70	Less beta attention for LCD
12.69	1.58	Less beta attention for LCD
42.00	21.17	Less beta attention for LCD
67.01	74.95	
12.55	17.81	
34.02	23.88	Less beta attention for LCD
25.18	18.71	Less beta attention for LCD
-5.27	18.49	
35.03	-0.35	Less beta attention for LCD
57.75	68.43	
55.84	36.25	Less beta attention for LCD
68.96	59.43	Less beta attention for LCD
-5.19	16.01	

The preliminary data above suggest a difference in the overall beta patterns in the parietal lobes. Nine subjects show less attention to the LCD screen and six subjects show less attention to print. However, the significance test following indicates there is not a significant difference. The hypothesis is rejected.

Table 4-22. Wilcoxon Signed Rank Test for Significance **p=.10**

Variables		N	Mean Rank	Sum of Ranks	
LCDBetaPar - PrintBetaPar	Negative Ranks	9	8.56	77.00	LCDBetaPar < PrintBetaPar
	Positive Ranks	6	7.17	43.00	LCDBetaPar > PrintBetaPar
	Ties	0			LCDBetaPar = CRTBetaPar
	Total	15			

Test Statistics • Wilcoxon Signed Ranks Test

	CRTBetaPar - PrintBetaPar	
Z	-0.966	Based on positive ranks
Asymp. Sig. (2-tailed)	.334	

The summary table 4-24 shows that both print and LCD screens provide greater attention patterns for reading than CRT screens. There is no difference detected between print and LCD. This would indicate the difference in the flicker of the screen and not the radiant nature of the light source.

Table 4-24. Summary of Findings

	Occipital Lobes	Parietal Lobes
Research Question One		
Print Will Show Greater Attention Than CRT		
Measured by Alpha Blocking	H1 Accepted	H2 Accepted
Measured by Beta Activity	H3 Rejected	H4 Accepted
Research Question Two		
LCD Will Show Greater Attention Than CRT		
Measured by Alpha Blocking	H5 Rejected	H6 Accepted
Measured by Beta Activity	H7 Rejected	H8 Accepted
Research Question Three		
Print Will Show Greater Attention Than LCD		
Measured by Alpha Blocking	H9 Rejected	H10 Rejected
Measured by Beta Activity	H11 Rejected	H12 Rejected

While not part of the original research questions, nor hypotheses presented *a priori*, the obvious question that arises is whether there is a difference between print materials under fluorescent lighting and the CRT screen as each will have a flickering effect.

Table 4-23. Comparison of brain wave activity for CRT and Florescent-lighted print.

Ranks

		N	Mean Rank	Sum of Ranks	
CRTAlphaOccRead - FlorAlphaOccRead	Negative Ranks	6	11.33	68.00	CRTAlphaOccRead < FlorAlphaOccRead
	Positive Ranks	9	5.78	52.00	CRTAlphaOccRead > FlorAlphaOccRead
	Ties	0			CRTAlphaOccRead = FlorAlphaOccRead
	Total	15			
CRTAlphaParRead - FlorAlphaParRead	Negative Ranks	13	7.31	95.00	CRTAlphaParRead < FlorAlphaParRead
	Positive Ranks	2	12.50	25.00	CRTAlphaParRead > FlorAlphaParRead

	Ties	0			CRTAlphaParRead = FlorAlphaParRead
	Total	15			
CRTBetaOccRead - FlorBetaOccRead	Negative Ranks	9	7.56	68.00	CRTBetaOccRead < FlorBetaOccRead
	Positive Ranks	6	8.67	52.00	CRTBetaOccRead > FlorBetaOccRead
	Ties	0			CRTBetaOccRead = FlorBetaOccRead
	Total	15			
CRTBetaParRead - FlorBetaParRead	Negative Ranks	10	8.60	86.00	CRTBetaParRead < FlorBetaParRead
	Positive Ranks	5	6.80	34.00	CRTBetaParRead > FlorBetaParRead
	Ties	0			CRTBetaParRead = FlorBetaParRead
	Total	15			

Test Statistics • Wilcoxon Signed Ranks Test

	CRTAlphaOcc-FlorAlphaOcc	CRTAlphaPar-FlorAlphaPar	CRTBetaOcc-FlorBetaOcc	CRTBetaPar-FlorBetaPar
Z	-.454[a]	-1.988[a]	-.454[a]	-1.477[a]
Asymp. Sig. (2-tailed)	.650	.047	.650	.140

a Based on positive ranks.

These comparisons show that there are additional significant differences that show up between print lighted by fluorescent and the CRT screen, again in the parietal lobes. Even though both would have the flicker effect, it may be more pronounced when shining directly into the eye. This could be an area for future study.

CHAPTER FIVE • DISCUSSION

Chapter Five will summarize the findings from the previous chapter and look at each research question independently. Then overall conclusions will be discussed from these individual questions and the conclusions will show how these new findings relate to the original theories and the larger body of literature. Specific contributions will be noted along with suggestions for further study to help answer additional questions raised by this work.

Summary of findings

This study indicates that a substantial number of subjects (more than 2:1) show greater attention patterns to reflected-light print media for reading than to radiant-light computer cathode ray tube (CRT) screens. The study shows little difference when comparing print media to liquid crystal display (LCD) screens, indicating that flicker, not radiant light shining in the eye, is the most likely cause of the attention differences. While the sample size is small with 15 subjects, the results are statistically significant.

Specifically, the findings indicate that attention differences are minimal in the ventral stream or occipital lobes, but do show up at the very earliest levels of processing of visual information through the dorsal stream and the parietal lobes. Subjects show statistically significant differences in brain wave patterns indicating less attention for reading text on CRT screens than print materials. From the findings it appears that the attention differences are due to the flicker effect of the CRT computer screens. When the CRT screens (which have a flicker even if it is not consciously registered) are tested against LCD computer screens (that do not have a flicker) similar differences are evident as for the print vs. CRT stimuli. Testing print vs. the LCD does not register the attention differences.

From the findings, it becomes obvious that one should not assume that materials presented in print and on computer screens will be attended to, nor processed by the brain, in the same manner. One should also not assume that all computer viewed information will be processed equally.

This exploratory study supports the work of Edelman, that even for the same stimuli there can be very different brain processing occurring. While this study looked specifically at the primary visual processing areas of the brain, each individual will have different re-entry processes based on personal experiences and individual differences.

Basar proposes the EEG as a way to measure the various brain rhythms which serve as an "alphabet of the brain." This study builds on that concept and proposes and tests a method to analyze EEG data to control for the individual differences and provides a way to statistically test the brain wave measurements rather than simply using a case study approach. This allows extrapolation of the findings to a larger population even with the small sample size. Caution must be used, however. While fifteen subjects is a typical sample for EEG studies, this must be considered exploratory research due to the limited number of subjects. This study has limitations in that it used all female and Caucasian subjects to limit the variables in the experimental design, but more work needs to be done with large sample sizes that would allow additional statistical analysis of the data and allow for a broader range of subjects.

The implications for distance education are important, as are commercial applications such as news delivery and advertising. Few previous studies have investigated whether subjects attend to and read material as well when presented on computer screens as in books or other print formats. It appears that there are significant differences with less attention being paid to CRT-type computer screens.

Discussion

To further analyze the data and present conclusions, each of the three research question will be discussed and then overall conclusions will be presented.

Research Question One: Does the light source affect the visual processing areas of the brain (occipital and parietal lobes) differently?

Analysis by Alpha Activity

The first two hypotheses deal with alpha blocking in the occipital and parietal lobes of the brain. When a subject goes from eyes closed (high alpha rhythm) to eyes open, one would expect alpha blocking to occur in every case. For one subject there was no alpha blocking for either medium and Basar (1999) points out that this can be considered normal, but rare. Of the remaining 14 subjects all but one (7%) did exhibit alpha blocking for print materials in the parietal lobes and the overall research indicates this dorsal stream is where the differences occur. One would expect the same to happen for subjects viewing thethe CRT screen but three of the 14 subjects (21%) or three times as many, did not exhibit alpha blocking.

The averages indicate overall alpha blocking for both occipital and parietal lobes. In both lobes, there is more alpha blocking for print materials than CRT screen. In general, this would indicate more attention, on average, for the print materials.

As expected, alpha blocking was exhibited in the majority of the cells (15 subjects x 2 treatments x 2 brain locations= 60 cells and 48 exhibited alpha blocking). However, as the alpha blocking is well documented in nearly all patients, the fact that nne subjects, more than half the total subjects, did not exhibit the alpha block in at least one cell is quite interesting.

Table 5-1 Absence of Alpha Blocking in Subjects

Subject one:	No alpha block in CRT Occipital
Subject two:	No alpha block in Print Occipital
Subject three:	No alpha block in CRT Occipital
Subject four:	No alpha block in CRT Parietal
Subject five:	No alpha block in Print Parietal
Subject nine:	No alpha block for CRT Occipital
	No alpha block for CRT Parietal
	No alpha block in Print Occipital
Subject ten:	No alpha block in CRT Parietal
Subject eleven:	No alpha block in CRT Parietal
Subject thirteen:	No alpha block in Print Occipital

There are obvious individual differences that occur in processing in both print and CRT. Seven of the eleven instances show an increase of alpha for CRT screens (rather than the anticipated alpha blocking.) This would support Krugman's (1971) study on television which showed an increase in Alpha activity and loss of attention for television type screens which have similarities to CRT screens.

The original hypotheses stated "The first two hypotheses are almost a given…" that alpha blocking would occur. However, as over half the subjects did not exhibit alpha blocking in all situations (especially CRT screens), it raises interesting questions. The alpha response, as explained by Basar (1998, V. 1, p. 121), can vary widely depending on the area of the brain being observed and recorded. The response is also very dependent on whether or not the stimulus is adequate for the neurons to fire. As Basar (1998, V. 1, p. 31) reports, "The normal alpha rhythm varies in amplitude and spatial distribution from one individual to another, and occasionally individuals possessing a normally functioning brain may never show an alpha rhythm."

The findings indicate that the entire "visual processing areas" of the occipital and parietal lobes should not be considered one unit. The data suggest that the two lobes react differently to different media sources. The original Krugman study simply used one electrode placed on the occipital lobe (exact location unspecified) to measure the entire visual processing area. The research presented here would indicate that this is not an adequate measurement as there will be differences in the lobes and both lobes need to be measured to adequately determine the firing patterns.

It also confirms the general theory that individual responses may vary widely as indicated by both Edelman and Basar. The data indicate that, yes indeed, the print medium and the CRT medium are processed differently from one another in the occipital and parietal lobes.

Analysis by Beta Activity

The alpha activity showed differences in processing by media for the occipital and parietal lobes with greater attention patterns for print materials. Overall, the beta activity shows little difference in the occipital lobes, but significant difference in the parietal lobes. For the occipital lobes, seven subjects showed less attention as measured by beta activity for the CRT screen treatment and eight subjects showed less attention as measured by beta activity for the print treatment. The differences are not statistically different.

The occipital lobes are primarily processing the very early visual information coming from the eye. Individual neurons or small clusters of neurons will fire when a particular shape, form, color, line direction, etc. is encountered. As both the print and CRT screens were using nearly identical black text on a white background there would be little variation in these shapes, forms or color processing in the occipital lobes. Beta is generated when the brain is showing more neuronal load to process and interpret information. Given that the reading level of the selection was approximately sixth to seventh grade level, there would most likely have been little difficulty or cognitive load required for processing the stimuli used.

This evidence from this study indicates that the nature of the light source, radiant versus reflective, does not <u>in itself</u> create a difference in beta wave activity. The radiant light shining directly into the eye does not appear to create a beta pattern differently for reflective media than radiant light media in the occipital lobes. However, luminance and light are processed by the parietal lobes and there are differences evident there as seen by acceptance of H4. More study needs to be done in this area, however as the simple black and white reading stimuli may have not had a large effect on the occipital lobes and the EEG measure does require a substantial change of firing of the neurons to register. Further testing with photos or other graphic materials should be pursued.

The results for the parietal lobes are much more striking. For the parietal lobes, 10 subjects (66%) showed less attention as measured by beta activity for the CRT screen treatment and five subjects showed less attention as measured by beta activity for the print treatment.

Table 5-1. Comparison of means for beta rhythm in the parietal lobes Print vs. CRT

Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
PrintBetaPar	15	-5.27	75.37	40.61	27.79
CRTBetaPar	15	-144.15	64.12	9.89	55.60
Valid N (listwise)	15				

The descriptive statistics indicate that not only was there more beta activity for the print treatment, the variation was also much less.

The statistical analysis shows a significant difference in the parietal lobes with more beta processing for print than the CRT screen indicating a higher level of attention for the print materials.

The parietal lobes have many functions, but the lower portion measured in this study primarily process luminance. However, the left hemisphere parietal is also important for processing language recognition in the immediately adjacent area. Given that the reading stimuli were controlled, nearly identical pieces of text, the language processing required by the treatment should not create this observed difference. The major difference in treatment is the light source shining in the eye. This research indicates significant differences in the way the parietal lobes react to light sources when reading. Table 5-1 above indicates that there is wide variation in subjects and the higher mean score for print shows a 40% average movement from the baseline (greater strength of attention) for the print treatment and less than 10% for the CRT screen.

As the parietal lobes process luminance, language and help to direct motion such as eye movement and saccades, it is possible that the effect of a direct light shining into the eye creates difficulty in the reading process. The studies conducted by Phillips Lighting suggest that flicker can cause a problem and that levels of luminance can cause stress and affect EEG. Determining the cause of the difference is the subject of the remaining two research questions. Question two examines the flicker effect and question three explores if it is the radiant light shining into the eye.

Research Question Two:

Do mechanical artifacts such as flicker on a CRT screen create different brain patterns in these visual processing areas when reading?

Analysis by Alpha Activity

Here, the four hypotheses are identical but deal with the mechanical artifact of flicker as the cause of differences that show up in the parietal lobes. The flicker effect is tested by comparing CRT screens, which do have a flicker effect, with LCD screens, which do not.

The first two hypotheses deal with alpha blocking in the occipital and parietal lobes of the brain as the method to determine attention differences. When a subject goes from eyes closed (high alpha rhythm) to eyes open, one would expect alpha blocking to occur in every case.

As the evidence indicated in research question on, when examining the ventral stream, the occipital lobes do not show a great difference in alpha blocking and the reasons would be same as those discussed in the difference on print vs. CRT. The occipital lobes are processing very basic shapes and forms and the treatment was nearly identical between the two tests.

As in the previous question, it is in the parietal lobes where differences do appear. Although one subject did not exhibit alpha blocking for either LCD or CRT screens all 14 remaining subjects viewing LCD did show the anticipated alpha blocking compared to only 73% for the CRT.

This would indicate that the flicker effect affects at least some of the subjects in a way that decreases attention. Again, this shows up in the parietal lobes, which process luminance, assist in directing attention and saccadic leaps and process language in the left hemisphere.

Analysis by Beta Activity

First the ventral stream and occipital lobes are considered. Once again, as with the print and CRT treatment, there is no significant difference between the CRT and LCD treatments. The occipital lobes are simply processing the forms, lines and colors and media makes little difference.

Next the dorsal stream and parietal lobes are considered. As with the print and CRT treatment, there is a significant difference between the CRT and LCD treatments that again shows up in the parietal lobes. This would indicate that it is the parietal lobes that are sensitive to the flicker effect. While the first research question indicates that light might be the cause of decreased attention to computer screens while reading, this question suggests the cause to be flickering of the screen. The two computer screens would both be sending light directly to the eye with comparable amounts of luminance, glare or other factors.

This work supports and extends work that has been done on the flicker effect of fluorescent lighting. Work done by von Bommel, et. al. at Phillips lighting show a higher "stress" level in the brain when fluorescent lights with flicker are compared to fluorescent lighting that does not have the flickering effect present. Another study showed the human brain continues to react to the flicker even when the flicker is no longer consciously discernable (Knez, 2003) and tested high frequency fluorescent and lower frequency fluorescent office lighting in three "color temperatures". The study by Knez did not report any cognitive effect or differences due to flicker, only a <u>self-reported</u> affective difference with the subject feeling less enthused, lively or relaxed with the flicker lighting.

The study presented here does not rely on such a subjective self-report method and is able to better pinpoint differences in the visual processing through the EEG measure. Even though the screen refresh rate was set high enough not to have flicker visible, it confirms the previous work cited that even though not visible, the flicker still affects the brain. In this study, attention is shown to decrease and as attention is crucial to cognition, it could be extended there is a likelihood overall cognition will also decrease. More study beyond the visual processing area such as the pre-frontal cortex should be examined to look for clues in cognitive processing differences. Other studies, using cats with electrodes inserted in the brain, indicate not only a difference in how the eye processes this flickering light in the visual processing areas, but indicates that the effects extend to other areas of the brain as well (Eysel, 1984). This current study extends Eysel's work by showing that the flickering effect seems to affect humans as well as cats, but again, further study should be done to see if the effect extends beyond the visual processing areas. This study also extends the work done on flicker by fluorescent tubes used by Eysel to include the flicker in CRT screens. Eysel's studies were done before widespread use of the computer and these findings indicate that the effects are similar.

The first two questions provide key findings of this study. The first question determines that there are noticeable differences in attention patterns between print and CRT screens. This second question narrows the possible cause down to the flicker effect as similar differences are shown to exist between types of computer screens with and without flicker.

This then would lead one to the final question. If flicker is the problem, and not the luminance itself, there should be few detectable differences between the print treatment and the LCD treatment as neither would exhibit the flicker effect. Yes, the luminance would be different, but no flicker would be present in either treatment. This logical conclusion to the study becomes the subject of research question three.

Research question three:

If there is a difference, is it due to the flicker effect or radiant lighting versus ambient lighting?

Analysis by Alpha Activity

To test this question, the radiant light, non-flicker LCD screen can be tested against the ambient light print treatment, which also lacks any flicker effect as it has incandescent lighting.

Once again, the first measure attention difference is to look to the Alpha block.

As anticipated from the previous findings there is little difference found when analyzing the alpha blocking in either ventral or dorsal stream for these treatments. Both the hypotheses were rejected. As in the other treatments, the occipital lobes are simple processing the forms and so no differences are detected.

Unlike the previous two comparisons, there is also no difference in the parietal lobes. In the other two comparisons, Print vs. CRT and LCD vs. CRT difference did appear in the parietal lobes for the CRT screens. The fact that no difference is detected here would once again point to the flicker effect as the source of difference as flicker is the main variable that is absent in the Print vs. LCD treatment.

Analysis by Beta Activity

Again, here there was no significant difference detected in the ventral stream and in fact the statistics showed the treatments to be equivalent with a test statistic of 1.00.

Hypothesis 12 is also rejected, showing no difference in the dorsal stream or parietal lobes. These findings indicate that it is not the radiant light shining in the eye, but the flicker effect of the CRT screen that makes a difference.

Final Conclusions

Occipital lobes show limited reaction to media differences

These findings indicate overall, that there is very little difference by medium in the occipital lobes, when reading text. This would support Edelman's theory of developmental selection. The brain is very specific in this information processing. Edelman's Theory of Neuronal Group Selection has helped us understand how the brain forms neural pathways, clusters, and areas to process information. We know from the extensive research done on the occipital lobes that there are neurons or small groups of neurons that are VERY specific in their response to stimuli. In some cases a specific neuron will only fire if a line is at a particular angle or a color is a particular wavelength of light. Medium seems to make little difference on the ventral stream which leads to the occipital lobes to process object identification and color (sometimes named the "what" stream). However, color was not tested in this study as all materials were black and white.

The alpha response is considered a resting brain state and is most often found strongly in the occipital lobe of the brain. In the brain there is almost always background firing of neurons. Coding is superimposed on this background of incessant, irregular discharge. Neurons processing similar inputs are organized together, receiving the same kinds of messages on the whole and transmitting the same kind of coded input to another cluster of neurons. Because of the incessant background noise, the responses of one neuron are lost but when they group together the signal is strong enough to be "heard" by the EEG. In other words, the neurons have to "shout together", as it were, to get the message across and so make a reliable signal despite all the background noise.

Previous work in cats shows that this ventral stream may be sensitive to the flicker effect, but this work measuring attention in humans does not support that. However, the work done with cats embedded the electrodes in individual neurons and this study looked at overall EEG patterns in which numerous neurons would have to fire simultaneously to change the EEG patterns. So it is possible that the flicker does affect this area, but it does not show up in the more macro measurements of the lobes used in this study by using EEG as the measure.

For the scope of this study, with a tightly defined sample, there appears to be little difference between media in the occipital lobes as the neurons decipher the information coming in from the eye. Since the path from the retina of the eye to the neurons involves relatively few intervening neurons and is quite direct, there is little interaction or feedback loop from extraneous stimuli in the ventral stream.

There is some indication, though, that while as a group, subjects did not vary significantly, there was wide variation from individual to individual. This supports the work of Edelman and Basar. While individual areas of the brain are known to process certain types of information, experiential development and individual patterns will cause each individual to have different brain wave patterns even if the same final conclusions or outcomes are noted. Therefore, one of the strengths of this study and a major contribution to the field is the development of a method to quantify the brain wave reactions in a way that allows one to compare the shift in brain waves while functionally eliminating these individual differences.

Parietal lobes react differently to different media, possibly due to flicker

Moving on to the parietal lobes, it is not surprising that this is where the differences in attention to various media appear. It is known that the parietal lobes process language in the left hemisphere. The caudal or posterior sections receive direct and indirect information from the primary visual cortex and the remaining section is involved in sensio-motor activity. In particular, the parietal lobes are increasingly considered at the interface between perception and action (Macaluso and Driver, 2003). The parietal lobes have been well-studied in monkeys and the research supports the role of the superior parietal lobes in attention, space recognition and visual approach. On the whole, the parietal lobes have a role in attention, visual processing and visual integrations, and language.

Therefore the parietal lobes are crucial for directing attention in the reading process. While the posterior parietal lobes process visual information, other parts of the parietal lobes direct movement, including eye movement, which has an affect on attending and the movement of the eye in saccades. For the print/reflective materials, there is more beta activity in the parietal lobes than the occipital lobes, indicating that the parietal lobes are more active and processing information. For the CRT screen, there is less activity in the parietal lobes than the occipital lobes, indicating that the parietal lobes are less active and processing less information. As attention is linked to the frontal and parietal lobes, especially in the right hemisphere, this could indicate lower attentiveness and perhaps decreased eye movement. Looking at eye tracking while reading on screen versus print might answer the question.

Need for further study

This study, exploratory in nature, indicates the need for additional study. First, this study looks at just three media sources: print viewed under incandescent light, CRT screens and LCD screens. Studies in industrial settings show workers perform differently under fluorescent and incandescent lighting. While not part of this study, a brief look at the fluorescent lighting and CRT screens indicates that there is less attention for the CRT screens even when compared with a similar (flickering) fluorescent-lighted print. This would indicate that more work needs to be done to answer questions raised by this study. Is there an interaction with the flicker and the radiant nature of the light that causes problems beyond the flickering effect alone?

This study measured only attention. As attention is a crucial step in cognition, it would follow that cognition and memory would also be affected and this should be measured for various media sources. The work done by Eysel indicates that the flickering extends beyond the visual areas of the brain to other areas and studies done by Knez also indicate there can be affective and psychological impacts from flicker as well. All these indicate there may be significant differences in reading ability, cognition and memory based on media selection. In particular, CRT screens seem to negatively impact attention in the parietal lobes where language is processed. Does this extend to true cognition and memory of reading material?

The implications for distance education are important, as are commercial applications such as news delivery and advertising. Few previous studies have investigated if subjects attend to and read material as well when presented on computer screens as in books or other print formats. It appears from this study that there are significant differences with less attention being paid to CRT computer screens. This work would confirm what many seasoned educators know anecdotally: that when asked to read difficult material on screen, many students will print it out to be able to comprehend. If there is no true difference in LCD screens and print, then a simple solution is to eliminate CRT screens and remove the flicker effect.

If there is a difference based on the flicker effect, does this difference also show up in television viewing? Earlier studies indicate a person moves into an alpha state and metabolism lowers while watching television. Can this trend be avoided if the flicker is not present by using an LCD type or flat-screen television?

While this study indicates that flicker seems to cause the problems, it is not clear whether the problem is in the processing of the language in the parietal lobes or if it is in the eye movement and saccades used to smoothly read text. Previous work by Geske (1996) indicates that larger type faces are needed on screen for reading ease and it is possible that these large sizes make tracking lines of text easier as the eye returns from one line of text to the next. The flicker and radiant light source may interfere with the saccadic movements and more testing should be done in this area.

Finally, if people attend to the media differently, do these difference extend to other parts of the brain? Further study needs to be done to see if the pre-frontal, more cognitive, areas of the brain also show differences in EEG activity based on medium of delivery.

With all these questions, one over-riding question prevails as well. This study tested 15 young Caucasian females. It is possible that there are differences based on age, gender and ethnicity and larger studies that allow comparison of these groups should be considered.

Contributions of this study

This preliminary study indicates that there are many unanswered questions concerning the human computer interface in media versus the traditional print media. However, it also makes significant contributions to further the understanding of how the human brain reacts to relatively new computer technologies.

First, the media cannot be treated as one unified visual source as there are distinct differences in how the brain processes the visual information coming from different media. Differences in visual processing do exist between media sources. In part, this supports Marshall McLuhan's statement from decades ago: "the medium is the message."

Second, this study also supports that visual information may be processed differently in the dorsal and ventral visual streams and that when studying the impact of visual materials, these streams need to be looked at independently to find effects. Future EEG studies need to examine both the occipital and parietal lobes separately for a true understanding of the visual processing in the brain. A suggestion for future study would include measuring the left and right hemisphere of the parietal lobes separately as well to see if the differences observed are uniform or concentrated in the language processing areas.

Third, this research extends the work previous authors have done on the effects of flickering light on the brain. It supports the work of Eysel, Knez and others that shows even if the flicker is not obvious or consciously apparent, it can have a sub-conscious effect on information processing. This study tested reading and simple word patterns, but more work should be done to see if it applies to other types of visual information such as photos and moving images.

Fourth, it supports the work of Edelman and Basar that each individual will have considerably different response patterns based on individual differences. Both baseline activity and reactions vary widely.

Finally, based on these individual differences it is important to take these differences into account when analyzing the data. A new method of measuring the data and reporting it for statistical analysis is presented. This study simply looks at the very earliest foundations of reading in the visual processing areas of the brain. It makes significant inroads by creating a method accounts for individual differences in EEG's and allows for statistical testing of differences.

By examining the foundations of attention, one can assume that there will also be differences in cognition and memory and more work needs to be done to determine these differences. In an environment that relies heavily on computers to deliver information for education, business and in daily life it is important to understand how to best design and deliver messages that can be easily processed and understood. By understanding these differences, persons who design messages for different media can best tailor the design to fit the appropriate medium for maximum attention and cognition.

APPENDIX ONE

The charts below examine the Alpha, Beta and Theta for the occipital (O) lobes in the first three columns and the parietal (P) lobes for the last three columns.

The top half of the chart records the CRT computer screen treatment with eyes closed (EC) for the baseline reading and with eyes open and reading (READ). The difference and percent of change is then calculated for each treatment and each brain lobe. A summary of the attention pattern follows each subject.

Subject 1							
CRT	**Alpha O**	**Beta O**	**Theta O**	**CRT**	**Alpha P**	**Beta P**	**Theta P**
EC	15.91	45.43	10.57	**EC**	28.97	20.92	17.63
Read	25.62	42.91	9.18	**Read**	8.82	24.03	17.31
	-9.71	**2.52**	**1.39**		**20.15**	**-3.11**	**0.32**
% Change	**-61.03**	**5.55**	**13.15**	% Change	**69.55**	**-14.87**	**1.82**
PRINT	**Alpha O**	**Beta O**	**Theta O**	**PRINT**	**Alpha P**	**Beta P**	**Theta P**
EC	13.98	18.92	9.39	**EC**	25.65	12.03	15.89
Read	11.49	37.47	8.74	**Read**	5.25	7.04	4.24
	2.49	**-18.55**	**0.65**		**20.4**	**4.99**	**11.65**
% Change	**17.81**	**-98.04**	**6.92**	% Change	**79.53**	**41.48**	**73.32**

Occipital Lobes
CRT Alpha Block: No alpha block
Print Alpha Block: Yes CRT

Beta: Yes
Print Beta: No. Large movement away from attention

Parietal Lobes
CRT Alpha Block: Yes
Print Alpha Block: Yes. More for print.

CRT Beta: No
Print Beta: Yes

Overall, results are very mixed. No clear conclusion can be made.

Subject 2							
CRT	Alpha O	Beta O	Theta O	CRT	Alpha P	Beta P	Theta P
EC	12.09	7.63	9.58	EC	26.00	18.92	22.73
Read	4.03	4.17	8.31	Read	6.69	7.05	7.39
	8.06	**3.46**	**1.27**		**19.31**	**11.87**	**15.34**
% Change	**66.67**	**45.35**	**13.26**	% Change	**74.27**	**62.74**	**67.49**
PRINT	Alpha O	Beta O	Theta O	PRINT	Alpha P	Beta P	Theta P
EC	7.75	9.05	12.95	EC	30	24.61	23
Read	12.19	5.30	4.62	Read	6.5	6.44	6.25
	-4.44	**3.75**	**8.33**		**23.5**	**18.17**	**16.75**
% Change	**-57.29**	**41.44**	**64.32**	% Change	**78.33**	**73.83**	**72.83**

Occipital Lobes
CRT Alpha Block: Yes.
Print Alpha Block: No.

CRT Beta: Yes. Greater than for print
Print Beta: Yes

Parietal Lobes
CRT Alpha Block: Yes.
Print Alpha Block: Yes. Greater for print

CRT Beta: Yes.
Print Beta: Yes. Greater for print

Overall mixed results.

Subject 3							
CRT	Alpha O	Beta O	Theta O	CRT	Alpha P	Beta P	Theta P
EC	21.27	25.79	30.46	EC	14.87	13.08	12.14
Read	31.87	52.01	19.66	Read	10.14	11.08	5.90
	-10.60	**-26.22**	**10.80**		**4.73**	**2.00**	**6.24**
% Change	**-49.84**	**-101.67**	**35.46**	% Change	**31.81**	**15.29**	**51.40**
PRINT	Alpha O	Beta O	Theta O	PRINT	Alpha P	Beta P	Theta P
EC	40.04	26.05	22.30	EC	19.71	20.83	10.04
Read	9.48	19.10	8.97	Read	4.5	7.34	6.44
	30.56	**6.95**	**13.33**		**15.21**	**13.49**	**3.6**
% Change	**76.32**	**26.68**	**59.78**	% Change	**77.17**	**64.76**	**35.86**

Occipital Lobes
CRT Alpha Block: No. Negative alpha
Print Alpha Block: YES

CRT Beta: No. Large negative movement
Print Beta: Yes

Parietal Lobes
CRT Alpha Block: Yes.
Print Alpha Block: Yes. Much larger

CRT Beta: Yes.
Print Beta: Yes. Greater for print.

Overall much greater attention for print compared to CRT.

Subject 4							
CRT	Alpha O	Beta O	Theta O	CRT	Alpha P	Beta P	Theta P
EC	37.84	18.34	17.46	EC	6.80	8.49	5.84
Read	9.52	12.85	9.27	Read	6.82	5.49	8.59
	28.32	**5.49**	**8.19**		**-0.02**	**3.00**	**-2.75**
% Change	**74.84**	**29.93**	**46.91**	% Change	**-0.29**	**35.34**	**-47.09**
PRINT	Alpha O	Beta O	Theta O	PRINT	Alpha P	Beta P	Theta P
EC	32.00	22.23	20.01	EC	11.66	7.54	8.35
Read	11.52	9.57	8.62	Read	11.25	7.29	10.66
	20.48	**12.66**	**11.39**		**0.41**	**0.25**	**-2.31**
% Change	**64.00**	**56.95**	**56.92**	% Change	**3.52**	**3.32**	**-27.66**

Occipital Lobes
CRT Alpha Block: Yes
Print Alpha Block: Yes

CRT Beta: Yes
Print Beta: Yes. Considerably more.

Parietal Lobes
CRT Alpha Block: No
Print Alpha Block: Yes.

CRT Beta: Yes. Considerably more
Print Beta: Yes.

Overall greater attention for print compared to CRT but somewhat mixed.

SUBJECT 5							
CRT	Alpha O	Beta O	Theta O	CRT	Alpha P	Beta P	Theta P
EC	21.58	12.53	7.62	EC	7.94	6.41	5.34
Read	16.70	8.06	8.76	Read	7.81	15.65	9.48
	4.88	**4.47**	**-1.14**		**0.13**	**-9.24**	**-4.14**
% Change	22.61	35.67	-14.96	% Change	1.64	-144.15	-77.53
PRINT	Alpha O	Beta O	Theta O	PRINT	Alpha P	Beta P	Theta P
EC	12.44	13.23	9.79	EC	7.19	11.81	5.62
Read	8.07	6.00	6.69	Read	8.53	6.85	4.90
	4.37	**7.23**	**3.10**		**-1.34**	**4.96**	**0.72**
% Change	35.13	54.65	31.66	% Change	-18.64	42.00	12.81

Occipital Lobes
CRT Alpha Block: Yes.
Print Alpha Block: Yes, More for print

CRT Beta: Yes.
Print Beta: Yes. More for print.

Parietal Lobes
CRT Alpha Block: Slight, but yes.
Print Alpha Block: No.

CRT Beta: No. Large move away from att.
Print Beta: Yes.

Overall much greater attention for print compared to CRT.

SUBJECT 6							
CRT	**Alpha O**	**Beta O**	**Theta O**	**CRT**	**Alpha P**	**Beta P**	**Theta P**
EC	11.79	10.86	9.52	**EC**	12.85	12.38	9.37
Read	6.12	8.05	5.63	**Read**	5.30	8.23	4.89
	5.67	**2.81**	**3.89**		**7.55**	**4.15**	**4.48**
	48.09	25.87	40.86	% Change	58.75	33.52	47.81
PRINT	**Alpha O**	**Beta O**	**Theta O**	**PRINT**	**Alpha P**	**Beta P**	**Theta P**
EC	24.03	15.80	10.01	**EC**	18.02	13.53	10.13
Read	9.93	12.04	6.94	**Read**	7.06	7.43	5.40
	14.10	**3.76**	**3.07**		**10.96**	**6.10**	**4.73**
	58.68	23.80	30.67	% Change	60.82	45.08	46.69

Occipital Lobes
CRT Alpha Block: Yes.
Print Alpha Block: Yes. Greater for print

CRT Beta: Yes. Slightly greater than print
Print Beta: Yes.

Parietal Lobes
CRT Alpha Block: Yes.
Print Alpha Block: Yes. Greater for print.

CRT Beta: Yes.
Print Beta: Yes. Greater for print.

Overall mixed. Increased attention for print compared to CRT.

SUBJECT 7							
CRT	**Alpha O**	**Beta O**	**Theta O**	**CRT**	**Alpha P**	**Beta P**	**Theta P**
EC	8.70	21.00	10.72	**EC**	6.23	7.10	4.68
Read	8.32	9.35	8.27	**Read**	3.58	3.69	4.43
	0.38	**11.65**	**2.45**		**2.65**	**3.41**	**0.25**
% Change	4.37	55.48	22.85	% Change	42.54	48.03	5.34
PRINT	**Alpha O**	**Beta O**	**Theta O**	**PRINT**	**Alpha P**	**Beta P**	**Theta P**
EC	9.63	11.02	7.07	**EC**	6.67	7.65	7.17
Read	5.62	7.20	7.54	**Read**	3.98	6.69	3.41
	4.01	**3.82**	**-0.47**		**2.69**	**0.96**	**3.76**
% Change	41.64	34.66	-6.65	% Change	40.33	12.55	52.44

Occipital Lobes
CRT Alpha Block: Yes.
Print Alpha Block: Yes. Much larger print.

CRT Beta: Yes. More than print
Print Beta: Yes.

Parietal Lobes
CRT Alpha Block: Yes.
Print Alpha Block: Yes. Roughly equal.

CRT Beta: Yes. More than print.
Print Beta: Yes.

Overall greater attention for CRT compared to print.

SUBJECT 8							
CRT	**Alpha O**	**Beta O**	**Theta O**	**CRT**	**Alpha P**	**Beta P**	**Theta P**
EC	14.89	17.00	14.35	**EC**	8.77	8.10	11.46
Read	8.89	6.10	8.50	**Read**	6.55	4.93	3.92
	6.00	**10.90**	**5.85**		**2.22**	**3.17**	**7.54**
% Change	40.30	64.12	40.77	% Change	25.31	39.14	65.79
PRINT	**Alpha O**	**Beta O**	**Theta O**	**PRINT**	**Alpha P**	**Beta P**	**Theta P**
EC	15.56	12.23	14.12	**EC**	10.78	8.73	9.05
Read	7.04	5.66	7.01	**Read**	10.50	5.76	4.12
	8.52	**6.57**	**7.11**		**0.28**	**2.97**	**4.93**
% Change	54.76	53.72	50.35	% Change	2.60	34.02	54.48

Occipital Lobes
CRT Alpha Block: Yes.
Print Alpha Block: Yes. Greater for print.

CRT Beta: Yes. More than print.
Print Beta: Yes.

Parietal Lobes
CRT Alpha Block: Yes. More for CRT.
Print Alpha Block: Yes.

CRT Beta: Yes. Roughly equal.
Print Beta: Yes.

Overall somewhat mixed results. More attention for CRT.

SUBJECT 9							
CRT	**Alpha O**	**Beta O**	**Theta O**	**CRT**	**Alpha P**	**Beta P**	**Theta P**
EC	2.71	3.58	2.67	**EC**	4.17	4.09	3.94
Read	3.05	4.06	4.95	**Read**	4.29	4.99	7.03
	-0.34	**-0.48**	**-2.38**		**-0.12**	**-0.90**	**-3.09**
% Change	-12.55	-13.41	-85.39	% Change	-2.88	-22.00	-78.43
PRINT	**Alpha O**	**Beta O**	**Theta O**	**PRINT**	**Alpha P**	**Beta P**	**Theta P**
EC	3.98	3.41	5.58	**EC**	4.61	6.87	3.60
Read	2.84	2.82	4.24	**Read**	4.98	5.14	7.04
	1.14	**0.59**	**0.66**		**-0.37**	**1.73**	**-3.44**
% Change	28.64	17.30	24.01	% Change	-8.03	25.18	-95.56

Occipital Lobes
CRT Alpha Block: No.
Print Alpha Block: Yes. Greater for print.

CRT Beta: No. Negative attention.
Print Beta: Yes. Attention shown

Parietal Lobes
CRT Alpha Block: No.
Print Alpha Block: No.

CRT Beta: No.
Print Beta: Yes. Attention shown.

Overall, Less attention shown to CRT; more attention for print.

SUBJECT 10							
CRT	**Alpha O**	**Beta O**	**Theta O**	**CRT**	**Alpha P**	**Beta P**	**Theta P**
EC	28.00	22.06	33.91	**EC**	17.17	14.53	15.18
Read	11.80	29.43	16.20	**Read**	17.91	23.33	12.30
	16.20	**-7.37**	**17.71**		**-0.74**	**-8.80**	**2.88**
% Change	57.86	-33.41	52.23	% Change	-4.31	-60.56	18.97
PRINT	**Alpha O**	**Beta O**	**Theta O**	**PRINT**	**Alpha P**	**Beta P**	**Theta P**
EC	37.81	25.97	26.30	**EC**	26.64	16.89	19.94
Read	12.30	23.81	26.71	**Read**	16.90	17.78	14.18
	25.51	**2.16**	**-0.41**		**9.74**	**-0.89**	**5.76**
% Change	67.47	8.32	-1.56	% Change	36.56	-5.27	28.89

Occipital Lobes
CRT Alpha Block: Yes.
Print Alpha Block: Yes. Greater for print.

CRT Beta: No. Negative attention.
Print Beta: Yes.

Parietal Lobes
CRT Alpha Block: No.
Print Alpha Block: Yes.

CRT Beta: No.
Print Beta: No. But smaller than CRT.

Overall, more attention for print.

SUBJECT 11							
CRT	**Alpha O**	**Beta O**	**Theta O**	**CRT**	**Alpha P**	**Beta P**	**Theta P**
EC	9.21	10.54	6.92	**EC**	3.35	4.95	3.66
Read	7.99	8.05	9.96	**Read**	3.40	3.06	3.33
	1.22	**2.49**	**-3.04**		**-0.05**	**1.89**	**0.33**
% Change	13.25	23.62	-43.93	% Change	-1.49	38.18	9.02
PRINT	**Alpha O**	**Beta O**	**Theta O**	**PRINT**	**Alpha P**	**Beta P**	**Theta P**
EC	10.37	13.35	7.15	**EC**	3.94	5.31	3.79
Read	6.17	8.04	9.72	**Read**	2.34	3.45	2.93
	4.20	**5.31**	**-2.57**		**1.60**	**1.86**	**0.86**
% Change	40.50	39.78	-35.94	% Change	40.61	35.03	22.69

Occipital Lobes
CRT Alpha Block: Yes.
Print Alpha Block: Yes. Greater for print

CRT Beta: Yes.
Print Beta: Yes. Greater for print.

Parietal Lobes
CRT Alpha Block: No. Negative.
Print Alpha Block: Yes.

CRT Beta: Yes. Roughly equal.
Print Beta: Yes.

Overall more attention for print.

SUBJECT 12							
CRT	**Alpha O**	**Beta O**	**Theta O**	**CRT**	**Alpha P**	**Beta P**	**Theta P**
EC	36.34	17.07	9.67	**EC**	7.27	6.76	5.38
Read	8.42	18.18	11.70	**Read**	3.12	5.37	6.02
	27.92	**-1.11**	**-2.03**		**4.15**	**1.39**	**-0.64**
% Change	76.83	-6.50	-20.99	% Change	57.08	20.56	-11.90
PRINT	**Alpha O**	**Beta O**	**Theta O**	**PRINT**	**Alpha P**	**Beta P**	**Theta P**
EC	17.14	19.49	15.87	**EC**	7.02	10.20	4.86
Read	8.29	12.14	7.19	**Read**	4.16	4.31	3.47
	8.85	**7.35**	**8.68**		**2.86**	**5.89**	**1.39**
% Change	51.63	37.71	54.69	% Change	40.74	57.75	28.60

Occipital Lobes
CRT Alpha Block: Yes.
Print Alpha Block: Yes.

CRT Beta: No.
Print Beta: Yes. Greater for print.

Parietal Lobes
CRT Alpha Block: Yes. Greater for CRT.
Print Alpha Block: Yes.

CRT Beta: Yes.
Print Beta: Yes. Much greater for print.

Overall more attention for print as evidenced by negative patterns in beta and theta.

SUBJECT 13							
CRT	**Alpha O**	**Beta O**	**Theta O**	**CRT**	**Alpha P**	**Beta P**	**Theta P**
EC	10.54	10.44	4.68	**EC**	6.47	9.76	5.58
Read	3.56	10.23	3.17	**Read**	4.25	11.55	3.95
	6.98	**0.21**	**1.51**		**2.22**	**-1.79**	**1.63**
% Change	66.22	2.01	32.26	% Change	34.31	-18.34	29.21
PRINT	**Alpha O**	**Beta O**	**Theta O**	**PRINT**	**Alpha P**	**Beta P**	**Theta P**
EC	5.40	10.04	5.61	**EC**	4.32	6.25	2.91
Read	6.50	6.57	3.72	**Read**	2.61	2.76	2.60
	-1.10	**3.47**	**1.89**		**1.71**	**3.49**	**0.31**
% Change	-20.37	34.56	33.69	% Change	39.58	55.84	10.65

Occipital Lobes
CRT Alpha Block: Yes.
Print Alpha Block: No.

CRT Beta: Yes.
Print Beta: Yes. Much greater for print.

Parietal Lobes
CRT Alpha Block: Yes.
Print Alpha Block: Yes. Greater for print.

CRT Beta: Yes. Roughly equal.
Print Beta: Yes.

Overall more attention for print.

SUBJECT 14							
CRT	**Alpha O**	**Beta O**	**Theta O**	**CRT**	**Alpha P**	**Beta P**	**Theta P**
EC	26.31	35.74	20.59	**EC**	18.39	12.59	17.35
Read	9.40	5.80	13.23	**Read**	7.88	5.27	11.89
	16.91	**29.94**	**7.36**		**10.51**	**7.32**	**5.46**
% Change	64.27	83.77	35.75	% Change	57.15	58.14	31.47
PRINT	**Alpha O**	**Beta O**	**Theta O**	**PRINT**	**Alpha P**	**Beta P**	**Theta P**
EC	25.43	25.06	22.95	**EC**	26.36	16.46	17.99
Read	7.59	6.48	7.24	**Read**	5.71	5.11	6.02
	17.84	**18.58**	**15.71**		**20.65**	**11.35**	**11.97**
% Change	70.15	74.14	68.45	% Change	78.34	68.96	66.54

Occipital Lobes
CRT Alpha Block: Yes.
Print Alpha Block: Yes. Greater for print.

CRT Beta: Yes.
Print Beta: Yes.

Parietal Lobes
CRT Alpha Block: Yes.
Print Alpha Block: Yes.

CRT Beta: Yes.
Print Beta: Yes.

Overall more attention for print

SUBJECT 15							
CRT	**Alpha O**	**Beta O**	**Theta O**	**CRT**	**Alpha P**	**Beta P**	**Theta P**
EC	19.17	22.67	16.44	**EC**	10.53	9.71	9.50
Read	12.34	15.03	8.48	**Read**	4.22	4.75	3.75
	6.83	**7.64**	**7.96**		**6.31**	**4.96**	**5.75**
% Change	35.63	33.70	48.42	% Change	59.92	51.08	60.53
PRINT	**Alpha O**	**Beta O**	**Theta O**	**PRINT**	**Alpha P**	**Beta P**	**Theta P**
EC	24.59	19.80	12.68	**EC**	17.03	8.19	11.27
Read	10.93	13.76	11.99	**Read**	4.48	7.10	3.01
	13.66	**6.04**	**0.69**		**12.55**	**1.09**	**8.26**
% Change	55.55	30.51	5.44	% Change	73.69	13.31	73.29

Occipital Lobes
CRT Alpha Block: Yes.
Print Alpha Block: Yes. Greater for print.

CRT Beta: Yes.
Print Beta: Yes.

Parietal Lobes
CRT Alpha Block: Yes.
Print Alpha Block: Yes.

CRT Beta: Yes.
Print Beta: Yes.

Overall, results are very mixed. No clear conclusion can be made.

REFERENCES

Alluisi, E. A., Coates, G.D., & Morgan, B.B., Jr., (1977). Effects of temporal stressors on vigilance and information processing. Vigilance: Theory, operational performance, and physiological correlates. R. R. Mackie. New York, Plenum: 361-421.

Andreassi, J. L. (2000). Human Behavior and Physiological Response. Mahwah, N.J, L. Erlbaum, Publishers.

Basar, E. (1980). EEG-Brain Dynamics. Amsterdam, Elsevier.

Basar, E. (1999). Brain Function and Oscillations. Germany, Springer-Verlag Berlin Heidelberg.

Beatty, J., and O'Hanlon, J. F. (1979). Operant control of posterior theta rhythms and vigilance performance: Repeated treatments and transfer of training. Progress in operant conditioning of physiological events. Hillsdale, NJ, Lawrence Erlbaum Associates.

Beatty, J., et al. (1974). "Operant control of occipital theta rhythm affects performance in a radar monitoring task." Science 183: 872-873.

Berson, D. M. (2002). Melanopsin and phototransduction by retinal ganglion cells. Orlando, Fifth International LRO lighting research symposium.

Brainard, G. C. (2002). Photoreception for regulation of melatonin and the circadian system in humans. Orlando, Fifth International LRO lighting research symposium.

Brainard, G. C. e. a. (2001). "Action spectrum for melatonin regulation in humans: Evidence for a novel circadian photoreceptor." Journal of Neuroscience.

Czerner, T. B. (2001). What Makes You Tick? The Brain in Plain English, Wiley.

Edelman, G. (1989). The Remembered Present. New York, Basic Books, Inc.

Edelman, G. (1993). Bright Air, Brilliant Fire: On the Matter of the Mind. New York, BasicBooks.

Edelman, G. (2004). Wider than the Sky. New Haven and London, Yale University Press.

Edelman, G. M. (1987). Neural Darwinism. New York, Basic Books, Inc.

Edelman, G. M., and Tononi, Guilio (2000). A Universe of Consciousness. New York, Basic Books, Inc.

Edelstein K, M. N. (2001). "Behavioral responses to light in mice with dorsal lateral geniculate lesions." Brain Research Nov 9.

Emery, E. A. The Emery Report on Television. Australian National University at Canberra's Center for Continuing Education. Australia.

Eysel U.T., a. B. U. (1984). "Fluorescent light evokes flicker responses in visual neurons." Vision Research 24(9): 943-948.

Falk, D., Hildebold, C., Cheverud, J., et al. (1991). "Human cortical asymmetries determined with 3D MR technology." Journal of Neuroscience Methods 39(2): 185-191.

Ferwerda, J. A. (2001). "Elements of early vision for computer graphics." IEEE Computer Graphics and Applications, 21(5): 22-33.

Fessard, A. (1936). Propri,t,s Rythmiques de la Mati·re Vivante. Paris, Hermann.
Gale, A. C., B. (1987). Psychophysiology and the electronic workplace. London, John Wiley and Sons.

Geske, J. (1997). Readability of Body Text in Computer Mediated Communication. Presented at Association for Education in Journalism and Mass Communication, Visual Communication Division (Chicago), August 1997.

Giannitrapani, D. (1988). The EEG of Mental Activities. Karger, Basel, Switzerland.

Glickstein, M. (2003). "Subcortical Projections of the Parietal Lobes." The Parietal Lobes 93: 43-55.

Goldberg ME, B. M. (1981). "Behavioral enhancement of visual responses in monkey cerebral cortex. II. Modulation in frontal eye fields specifically related to saccades." Journal of Neurophysiology 46: 773-787.

Goldbeter, A. (1996). Biochemical Oscillations and Cellular Rhythms. The Molecular Bases of Periodic and Chaotic Behaviour. Cambridge, Cambridge University Press.

Goldbeter, A. (2002). "Computational Approaches to Cellular Rhythms." Nature 420:238.

Hebb, D. O. (1949). The Organization of Behavior. New York, New York.

Horst, R. L. (1987). An overview of current approaches and future challenges in physiological monitoring. Mental State Examination, (NASA CP-2504, pp.25-42).

Jan, J. E., and M. E. O'Donnell (1996). "Use of melatonin in the treatment of pediatric sleep disorders." Pineal Research 21: 193-199.

Knez, I. (2005). Non-Visible Flicker from Fluorescent Lighting: Psychological Impact. Proceedings: http://www.rightlight6.org/english/proceedings/Poster_Session/Non-Visible_Flicker/f011knez.doc.

Krugman, H. (1970). Electroencephalographic Aspects of Low Involvement: Implications for the McLuhan Hypothesis. Cambridge, MA: Marketing Science Institute.

Krugman, H. E. (1971). "Brain wave Measures of Media Involvement." Journal of Advertising Research 11(1): 3-9.

Küller, R., Wetterberg, L. (1993). "EEG, ECG and subjective comfort in healthy humans: impact of two fluorescent lamp types at two light intensities"." Lighting Research and Technology.

Kuller, R. a. L., T. (1998). "The Impact of Flicker from Fluorescent Lighting on Well-being Performance and Physiological Arousal." Ergonomics 41(4): 433-47.

Le May, M. (1976). "Morphological cerebral asymmetries of modern man, fossil man and non human primate." Annals of the New York Academy of Sciences 280: 349-366.

Lindsley, D.B (1960). Attention, consciousness, sleep and wakefulness. In J. Field, H.W. Magoun, & V.E. Hall (Eds.), *Handbook of physiology, neurophysiology III* (pp.1553-1593). Washington DC: American Physiological Society.

Lubar, J. F. (1991). "Discourse on the development of EEG diagnostics and biofeedback for attention-deficit/hyperactivity disorders." Discourse on the development of EEG diagnostics and biofeedback for attention-deficit/hyperactivity disorders 16(3): 201-55.

Lubar, J. F., and Shouse, M.N. (1976). "EEG and Behavioral Changes in a Hyperkinetic Child Concurrent with Training of the Sensorimotor Rhythm (SMR)." Biofeedback and Self-Regulation 3: 293-306.

McLuhan (1964). Understanding Media. Cambridge, Mass., MIT Press.

Mountcastle, V. B., J. C. Lynch, A. Georgopoulos, H. Sakata and C. Acuna (1975). "Posterior parietal association cortex of the monkey: command functions for operations within extrapersonal space." J Neurophysiology 38(4): 871-908.

Mulholland, T., and Erik Peper (1971). "Occipital Alpha and Accommodative Vergence, Pursuit Tracking, and Fast Eye Movements." Psychophysiology 8(5): 556-575.

Naatanen, Risto (1992) Attention and Brain Function. Hillsdale NJ: Lawrence Erlbaum Associates.

Natani, K., and Gomer, F. E. (1981). Electro-cortical activity and operator workload: A comparison of changes in the electroencephalogram and in event-related potentials. Long Beach, CA, McDonnell Douglas Corporation.

New England Journal of Medicine 343: 1070.

O'Hanlon, J. F., and Beatty, J. (1979). Vigilance: Theory, operational performance, and physiological correlates. New York, Plenum.

Olshavsky (1994), "Attention as an Epiphenomenon: Some Implications for Advertising". In Attention, Attitude and Affect in Response to Advertising, eds. Clark Eddie, M, Brock T.C., and Stewart D.W. Hillsadale, NJ: Lawrence Erlbaum Associates 1994

Parent, A. (1996). Carpenter's Human Neuroanatomy. Baltimore, Williams & Wilkins.

Roberts, J. P. (2004). "Melanopsin Lights the Way:A novel photoreceptor system solves one mystery while stirring up a few more." The Scientist 18(8): 32.

Robinson DL, G. M., Stanton GB. (1978). "Parietal association cortex in the primate: sensory mechanisms and behavioral modulations." J. Neurophysiology 41: 910-932.

Rossiter, J. R., & Percy, L. (1987). Advertising and promotion management. New York: McGraw-Hill.

Sanders, M. a. E. J. M. (1993). Human factors in Engineering and Design. New York, McGraw-Hill.

Sandhu, D., Fong, L., Rigney, J. (1996). "Teaching Students Through Their Culturally Specific Learning Styles." Journal of Accelerated Learning and Teaching 21(1&2): 60-84.

Satterfield, H. H., Lesser, L.I., Saul, R.E., & Cantwell, D.P. (1973). "EEG aspects in the diagnosis and treatment of minimal brain dysfunction." Annals of New York Academy of Science 205: 274-282.

Shouse M.N., Lubar, J. F. (1978). "Physiological bases of hyperkinesis treated with methylphenidate." Pediatrics 62: 343-351.

Shouse, M. N., Lubar, J. F. (1979). "Operant conditioning of EEG rhythms and ritalin in the treatment of hyperkinesis." Biofeedback and Self-Regulation 4(4): 299-312.

Sirevaag, E., et al. (1988). "A psychophysiological analysis of multi-task processing demands." Psychophysioloy 24: 482.

Sterman, M. B., et al. (1993). "Application of quantitative EEG analysis to workload assessment in an advanced aircraft simulator." Proceedings of the Annual Meeting of the Human Factors and Ergonomics Society 37: 118-21.

Tecce, J. J. (1972). "Contingent Negative Variation (CNV) and psychological processes in man." Psychological Bulletin 77: 73-108.

TG Publishing (2005). "Tom's Hardware Guide." http://graphics.tomshardware.com/display/19990624/tft1-07.html ; http://graphics.tomshardware.com/display/19990624/tft1-08.html.

Tufts (1999). Supermarket psych-out. *Tufts university health and nutrition letter,* 16, 1. http://www.homezone.com/stories/1376/646320.html.

Ungerleider, L. G. a. M., M. (1982). Two Cortical Visual Systems. Analysis of Visual Behavior. D. G. Engle, Goodale, M.A., and Mansfield, R.J.Q. Cambridge, MA, MIT Press.

van Bommel, J. M. a. v. d. B., G.J. (2003). Lighting for Work: Visual and Biological Effects, Phillips Lighting, Netherlands.

Wimmer, R. D., and Dominick, Joseph R (2000). Mass Media Research - An Introduction. New York, Wadsworth.

Zeki, S. (1993). A Vision of the Brain. London, Blackwell Scientific Publications.